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SCIENCE FOR CULTURE.*

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If there is anything the matter with science teaching one may be very hopeful that the difficulty will be cured when he considers the number of associations and clubs of science teachers formed to discuss plans for improving present conditions.

My subject needs a little definition.

Probably everyone who is teaching science is attempting to cultivate something. One aims at accuracy, skill, honesty of thought, discipline; another aims to cultivate imagination, power of generalizing, information, etc.

I have no disagreement with either party, except that they ought not to exist as parties. They should combine. The different departments of education should work toward one end. Certainly it cannot be the duty of one department to tear down what another constructs.

It is my purpose to speak of culture as we generally use the term when we speak of culture courses, liberal education, etc.

No one needs imagination more than the investigator and no one has a better opportunity to cultivate it than the teacher of physics. The scientist and the humanist have not conflicting duties—indeed there is no occasion to make a distinction between them. Humanism which is not scientific and science which is not humanistic are worthless.

Professor Cooke says, "Science culture differs in its methods from the old classical culture, but it has the same spirit and the same object."[1]

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*Paper read at the annual meeting of the Central Association of Science and Mathematics Teachers, University of Chicago, Nov. 30, 1906.

[1] J. P. Cooke—*Science Culture*, p. 20.

Professor Burr, speaking of the fundamental idea of the humanists, says, "It was their open purpose in which they gloried to treat of things as they actually existed, to get as near to the life of the community as the best knowledge would bring them; in other words, to touch human life intimately and at the greatest possible number of points."[2]

Let it be conceded that it is very desirable to cultivate accuracy, self-dependence, mental honesty, etc. There is no short cut —no royal road to these results. Such fruits do not come out of forty laboratory exercises. They are a slow growth of many years. Quantitative work simplified, made direct, and put in its proper sequence with qualitative work may profitably occupy, say one quarter of the effort of a high school pupil in physics. But science is something more than measurement. To be sure when men began to measure they took great strides forward, but it is equally true that research comes to a standstill when information and imagination are wanting. The chief difficulty with science teaching today, both in the high school and in the college, is that we do not give sufficient information.

Culture courses, or information courses, are often spoken of scornfully as a "smattering of all the 'ologies."

We have the mistaken idea that we can cut a clean swath in education; can teach a subject thoroughly; can treat a few principles and teach the whole truth about them first hand. But this is to attempt the impossible. Neither the immature nor the mature human mind works that way.

Dr. Simon Newcomb says: "The plausible system of learning one thing thoroughly before proceeding to another, and taking things up in their logical order only, should be abandoned. Let us train the pupil as rapidly as possible in the higher forms of thought and not be afraid of his having a little smattering of advanced subjects before they are reached in regular course. Let us remember that thoroughness of understanding is a slow growth, in which unconscious cerebration plays an important part, and leave it to be slowly acquired. A teacher aiming at thoroughness might have kept Cayley or Sylvester working half his life on problems of advanced arithmetic without reaching his standard of thoroughness."[3]

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[2] W. H. Burr—*Science*, Oct. 26, 1906.
[3] Simon Newcomb, *Educational Review*, April, 1906.

The teachers of De Morgan, the mathematician, found him dull in mathematics.

Let me recall the scene from that charming little book, "Philip's Experiments," where Philip and his father are surveying in the field when the Schoolmaster is introduced.

"Philip's schoolmaster pointed out that after he had had systematic training in geometry and trigonometry, he would have little difficulty with the problems which arise in surveying. He also said that the plane table should have a telescope instead of rude sights, and he described various accurate instruments, and intimated that I was cultivating habits of inaccuracy in Philip. Training in science which was not highly accurate he believed was worse than no training at all. I listened, but I remembered that this teacher had kept Philip at work making highly accurate measurements with a delicate balance. The boy had not appreciated the construction of the balance, for he had never made weighings with a rough instrument, and his mind had been kept so fixed upon the third place of decimals, that he did not appreciate what specific gravity really means. I could see that the schoolmaster in his endeavor to refine had forgotten the difficulties of an immature mind. Philip was on one contour line and he on another, and it would take more than a megaphone to put them into communication."[4]

"In obtaining quantitative work, exactness must be demanded, but exactness is a quality that comes relatively late in youthful minds as in that of the race. We are attempting to force nature; we are anticipating maturity of mind when we crowd into a curriculum subjects in advance of the time when the mind of the average boy or girl is able satisfactorily to pursue these subjects. * * * Probably the fault is not with the subject physics, but with the method. Too much quantitative work is demanded of both boys and girls; too little attention is given to the great names who have developed the subject and made inventions household words."[5]

We are too much afraid of teaching some things which have to be modified or even unlearned later. "Unlearning" is quite as educational as learning and does no harm to a reasonable being, indeed it may be a cure for bigotry. It is more important to cultivate openmindedness than it is to be correct.

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[4] John Trowbridge, *Philip's Experiments*, p. 79.
[5] William L. Felter, *Educational Review*, April, 1906.

Professor Hopkins in giving a simple, provisional definition of an acid, says, "At that stage of instruction this simple working definition is sufficient. More would be an enormity. What though the definition be untrue? The instruction, it is to be remembered, demands simplicity and progression—not truth. * * * It shows the subject presented not as a carefully completed, rounded and exact definition * * * but as a part-truth at first which grows with his capacity for understanding."[6]

We are too sensitive about being up to date with our facts and theories. Since it has become impossible for any man to keep up with the literature of more than one subject, men have become timid about teaching more than one subject. But it is not difficult to show that the man who keeps himself moderately well informed upon the progress in several sciences is better prepared to teach than the one who knows only one subject. The weakest thing about research today is that our men are not *widely* informed.

One who has traveled much and become familiar with types of country may find his way through an unknown territory and readily suspect it when he is approaching a spot sought for. The ant studying his grains of sand does not get this view of a country. It is the "bird's-eye" view. Sailors by extended experience become accurate observers of weather phenomena. Miners and farmers and horse dealers and experts of all kinds acquire their accuracy of knowledge chiefly by the extensive method.

Professor Trowbridge says, "The natural progress of our study of any subject is from the qualitative, or the comparatively rough evidence of our senses, to the quantitative."[7] He says we need the countryman's habit of "hefting" a thing before weighing it.

Teachers in languages are everywhere insisting upon the advantages of reading at sight and reading widely. Why should teachers of science be slow to learn the science of teaching?

We talk about trying to rid ourselves of preconceived notions but preconceived notions are quite essential to progress, and the ability to preconceive notions is absolutely essential to research. It is no argument against a gift that it is capable of perversion. We want to be put in control of our faculties, not deprived of them by education.

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[6] Arthur John Hopkins, *School Science*, April, 1904.
[7] John Trowbridge, *New Physics*, Preface.

We have reversed the natural order and tried to train high school pupils in induction. Using the forms of induction in the high school may be a species of dishonesty. After all the pupils learn not from the experiment but from the teacher or the text-book. We teach them to test carbon dioxide gas with lime water but we have to inform them that nothing else will turn lime water milky, and so it is only a roundabout way of telling them the whole story. We have great satisfaction in calling this the heuristic method, and we make the children prigs by leading them to think that they are acquiring knowledge first hand.

The self-activity that high school pupils need is that which they may get in the laboratory by doing experiments merely for the purpose of coming in contact with things—making their knowledge real—acquiring "a certain balance of judgment which comes from actual contact with things."

"The mind must rest upon physical laws for a comparative long period in order to understand their true significance."[8]

Pupils learn by imitation chiefly. Professor Trowbridge recommends performing in lectures the experiments which the students afterwards perform themselves in the laboratory.

In many schools throughout this country one may find eminently successful teachers of physiography who proudly acknowledge that they learned *by imitation* of Professor Wm. M. Davis both their subject and their method of teaching. I should characterize Professor Davis' method as an exceedingly skillful way of *giving the information* which his students could not acquire first hand in a thousand years, and his method is equally successful in preparing students for research or for teaching.

The teaching of science should accomplish the greatest possible good to the greatest possible number. The time was when education proceeded without much reference to the public. It was intended for the select few. A rapid change is in progress. Within recent years the public high schools have become the most important educational institutions in the country. They surpass the colleges in buildings, laboratory equipment and teaching force—not only in quantity but in quality. In the rapid growth of colleges, the available funds have not increased in proportion to the increase in number of students. The result is that the classes have been assigned inferior instructors.

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[8] John Trowbridge, *New Physics*, Preface.

The growth of research, by diverting funds and diverting men, has caused college teaching to deteriorate.

The general testimony of students is that they work much harder in the high school than in the college. Who knows how it might affect the intellectual and moral character of college students to have courses of instruction which were capable of absorbing their chief interest? So that they would not feel ashamed to say they were more interested in their studies than in their diversions.

Theoretically the pursuit of research ought to enrich one's teaching but in actual practice attention to the art of teaching wanes as attention to research increases. The first requisite of a teacher is to be actuated by a desire—a fervent desire—to instruct others. If one can work at research and not have that ardor dampened, it is well. But to hold a teacher's position and to scorn the work of teaching is simply dishonest and even though one's researches may be more valuable to the world than his instruction, those who have paid tuition for instruction have a just claim against him. Probably most of the money received from tuition fees and from endowment by undergraduate colleges was given for purposes of instruction, but after diverting much of this to the support of research and after giving the students very indifferent instruction, we tell them that their tuition fees do not cover the cost of their education.

These college students have a starvation course in measurements called physics. Their tutors having just passed through the same course with excessive specialization are suspicious of that expansive thing called culture. They affect to despise not only the public but all departments of learning other than their own. They surpass the theologians in narrowing down their lines of orthodoxy. Some teachers of science are like polarizers. The truth which gleams in all directions is narrowed down to one plane when it is transmitted by them. Their standards would unclass Davy, Faraday, Tyndall, Pasteur, Humboldt, Maxwell, Huxley, Agassiz, Cooke, Shaler and the like, for these men all preached the doctrine that science is good for culture and should be given to all. Those who interpret science as cold blooded and exclusive have not only nine-tenths of mankind against them but a majority of the men of science and particularly the leaders of all time.

Davy was a poet and his high literary abilities made him a great teacher and likewise aided profoundly his researches. All of the men mentioned above were Natural Philosophers with all the diversity of interests which that title indicates. All were humanists and many of them devoutly religious.

The influence of the college in all departments, classical as well as scientific, is toward driving culture, in the sense in which I am using it, out of the schools; first, by narrowing the education which it gives to those who go out to teach in the schools, and, second, by prescribing a syllabus for the schools narrowly interpreted by examiners and bigotedly enforced by readers of examination papers. The schools cannot even give a cultural course in music. The brevity of life makes it necessary to have everything count toward entrance into college, and the college accepts only musical mathematics. There is not a department which is not handicapped in this same way. It is impossible to teach anything as a culture when it is necessary to prepare for examination—particularly an examination set by another person. No one can justly estimate the progress and the proficiency of a class except one who has been with them throughout their study. If a supervisor's examination is thought to be necessary, let the teacher prepare the questions and submit both questions and answers to the supervisor. A "reader" in four minutes passing upon a year's work of a student wholly unknown to him is an absurdity.

I cannot look upon a syllabus as a blessing even though it may be prepared by a majority of the teachers. Why should uniformity be thought necessary or desirable? The "New Movement Among Physics Teachers" is very helpful so long as it keeps in a state of solution, but we may regret its crystallization. One may hope that if we must have a syllabus, it may be extensive enough to include all that may be desired by any considerable number of teachers, and that each teacher shall be allowed great freedom of choice within the syllabus.

The high schools are coming nearer in touch with the public mind every day. They are powerfully influencing public sentiment and are in turn being profoundly influenced by public sentiment. We have lately had evidence that science was in the ascendency in the minds of the people by their vast gifts for equipping schools and colleges for teaching science, but unless our teaching is adapted to the needs of the majority, we shall soon

see the funds drifting in other directions, or, what is more likely, we shall see ourselves drifted away from our moorings by the resistless tide.

In the ultimate analysis the same public supports the colleges and the schools. The college looks to the public for its funds, whether they be legacies or legislative grants or tuition receipts; it looks to the public for exemption from taxation; it looks to the public for the patronage of its sons and daughters. The public in turn demands of the colleges better service in the matter of giving instruction.

People have recently learned that they must square their lives according to physical principles and they and their children have turned to educational institutions for information with an eagerness that is irresistible.

Their children have increased the attendance upon the colleges fivefold in recent years, and they themselves have entered university extension courses in countless thousands. In some cases, the extension courses furnish quite as good instruction as any given at the university. Faraday was started on his course as a scientist by Davy's public lectures and Cooke says [9] that he got his first taste of real knowledge from the lectures at the Lowell Institute although he was a pupil in the Boston Latin School at the time—and that taste awakened an appetite which was never satisfied. Cooke says he eagerly sought the popular science of the day, which was vastly inferior to what we have today. We may now rank a few of the daily newspapers among our better teachers of Science. Huxley said, "Science is not solely for the men of science but for the people."

General courses in college should be culture courses. They should be what their name indicates—general surveys. A majority of the students in such courses will not and ought not to pursue the subject longer than one year, when we come to balance up the claims of all the subjects in a liberal course. Why then do the instructors persist in giving them that which is absolutely meaningless, unless it be joined to a protracted study of one subject for several years, and why do they give them that which properly belongs not so much at the beginning as at the end of the course in that particular subject? Such general-survey courses are quite as important to those who will go on to specialize in the subject as to the students who will pursue it

[9] J. P. Cooke, *Scientific Culture and other Essays*, p. 72.

no farther. Large knowledge acquired by general surveys in many fields is necessary before one can select and organize. During his career in high school and undergraduate college a student should be encouraged to take general cultural courses in each and all the Sciences whether his aim is to specialize or not.

"The time has already come when to know any one of the Sciences thoroughly it is necessary to know the rest; in fact, all the so-called natural sciences are different branches of one great science."[10]

It is not possible to get an elementary knowledge of any one science except by this process of browsing among many.

[11] "We have a duty to our children which we cannot avoid, if we would, and for which we shall be held responsible by our posterity. These children are entering life surrounded not only by all the wonders and glories of nature, but, also, by giant conditions, which, whether stationed on their path as a blessing or a curse, will inevitably strike if their behests are not obeyed. So far as science has been able to define these giant forms, it is our duty, as it is our privilege, to point them out to those we are bound to protect and guide; and in many cases it is in our power to change the curse into a blessing, and to transform the destructive demon into a guardian angel. After that command of language which the necessities of civilized life imperatively require, there is no acquisition which we can give our children that will exert so important an influence on their material welfare as a knowledge of the laws of nature, under which they must live and to which they must conform; and throughout whose universal dominion the only question is whether men shall grovel as ignorant slaves or shall rule as intelligent servants.

"It is perfectly possible for a child before fifteen years of age to acquire a real and living knowledge of the fundamental facts of nature on which physical science is based. This is not a question of natural endowment or special aptitude.

"To arouse a love of study in any subject is to take the first step toward making your man a scholar (I want to emphasize scholar), while to fail to gain his interest in any study is to lose the whole end of education."

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[10] Elisha Gray, *Nature's Miracles*, p. 170.
[11] J. P. Cooke, *Scientific Culture and other Essays*, p. 81.

[12] "We greatly wrong a pupil if we leave him unfitted to enter p. 635.
into the great inheritance of scientific truth obtained by past and present research. In striving to work out this problem let us, first, inculcate a habit of scientific thinking, second, give as wide a knowledge as possible, and third, awaken an interest which shall be lasting."

Mr. Roy Fryer says: [13] "That course is best which contributes most to general information and culture by acquainting the pupil with a wide range of chemical facts, while at the same time it trains his powers of observation and of reasoning from those observations." We make a great mistake when we shape our courses so as to eliminate all except those who are mathematically inclined and ready for specialization.

[14] "No educated man can expect to realize his best possibilities of usefulness without a practical knowledge of the methods of experimental science. * * * It is not to be expected or desired that many of our students should become professional men of science * * * (yet) any system of education is radically defective which does not comprise a sufficient training in the methods of experimental science to make the mass of our educated men familiar with this tool of modern civilization.

"The elementary principles and the more conspicuous facts of chemistry are so intimately associated with the experiences of every-day life, and find such important applications in the useful arts, that no man at the present day can be regarded as educated who is ignorant of them. * * * Physical Science has become a great power in the world. Indeed, after religion, it is the greatest power of our modern civilization. Consider how much it has accomplished during the last century toward increasing the comforts and enlarging the intellectual vision of mankind. * * * It is frequently said, in defense of the exclusive study of the records of ancient learning, that they are the product of thinking, loving, and hating men like ourselves, and it is claimed that the study of science can never rise to the same nobility because it deals only with lifeless matter. But this is a mere play on words, a repetition of the error of the old schoolmen. Physical Science is noble because it does deal with

[12] J. H. Denbigh, *School Science and Mathematics*, Oct. 1906, p. 635.
[13] Roy Fryer, *School Science and Mathematics*, Dec. 1906.
[14] J. P. Cooke, *Scientific Culture*.

thought, and with the very noblest of all thought. * * * The ancient logic never relieved a moment of pain, or lifted an ounce of the burden of human misery. The modern logic has made a very large share of material comfort the common heritage of all civilized men."

Teachers in their zeal for maintaining their standards often lose their missionary spirit and act as though they would exclude the large majority of students from the department of knowledge over which they preside. Their love for a particular science has overshadowed their love for their fellow men. Such are not true representatives of the men of science.

[15] "No teaching is of any real value that does not come directly from the intelligence and heart of the teacher and thus appeal to the intelligence and heart of the pupil. * * * There is no nobler service than the life of a true teacher; but the mere taskmaster has no right to the teacher's name, and can never attain the teacher's reward.

"Value scientific studies not simply because they cultivate the perception and reasoning faculties, but also because they fill the mind with lofty ideals, elevated conceptions and noble thoughts. Indeed, I claim that there is no better school in which to train the æsthetic faculties of the mind, the tastes, and the imagination than the study of natural science."

The history of science tells of a "multitude who have worked in faith for the love of knowledge" and "made themselves and their fellows more noble men."

The production of lead in 1905 was 302,000 short tons, as against 307,000 short tons in 1904 and 282,000 short tons in 1903. The value of the production in 1905 was $28,690,000, as compared with $26,402,000 in 1904, and with $23,520,000 in 1903.

The production of iron ores in 1905 in the United States amounted to 42,526,133 long tons, as compared with 27,644,330 long tons in 1904, with 35,019,308 long tons in 1903, and with 35,554,135 long tons in 1902, a gain in 1905 over 1904 of 14,881,803 long tons, or about 54 per cent. The value at the mines of the ore mined in 1905 was $75,165,604, a gain as compared with the 1904 value, $43,186,741, of $31,978,863, or 74 per cent. As in the six preceding years, the production of iron ores in the United States in 1905 was never equaled by that of any other country.

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[15] J. P. Cooke, *Scientific Culture.*

THE NORMAL ORDER: OPENING PROPOSITIONS IN GEOMETRY.

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Every text-book in geometry has its own peculiar order of opening propositions; all more or less arbitrary and unsuggestive. The question often rises, Which is the best order? To answer this, one must add the counter question, For what purpose?

It is assumed here that the purpose is to help the student along the line of least resistance; along the line of apperceptive receptivity and at the same time along a suggestive line; along a path which appeals to the initiative of the student; along a path which enables the student to feel that he is *doing* rather than being led; along a path which will seem to him natural rather than artificial.

Many students object intellectually and verbally to the arbitrary order of the text-books; to the interjection of propositions without any apparent reason for them or anything to suggest them. For instance, why begin with equal triangles? To this the only reply of the teacher can be: The author from his large experience deemed this the best order. But, says the student, I have no experience; is there no way in which I can *do for myself* as in other sciences; discover my own facts and collate them? The impulse is to answer, No, not unless you are a genius.

But this is all wrong. Any intelligent student ought to be able to build up and can build up a system for himself, provided he has an intelligent understanding of—

What he is trying to do;

Wherewith he is trying to do it;

Why he selects certain constructions.

With these three equipments, the *How* will readily fall in line. What is he trying to do? To wit, study the metrical (measurable) things which result from the placing of straight lines in a plane. For the doing of this he has only the axioms and those theorems which he is able to build up as he goes along. Thus the equipment at the start is a bundle of *indefinite* lines and *axioms.*

(a) Only one straight line.
(b) A straight line is shortest.
(c) Coincident magnitudes are equal.
(d) Only one parallel through a point.

Begin simply with one thing at a time and build up gradually. The placing of *one* indefinite line on the plane gives nothing metrical.

A *second* line introduces *angles* and their discussion and furnishes, as soon as the straight angle has been identified, the theorems.

(e) Sum of the angles on a straight line=a straight angle.

(f) Sum of the angles on a broken line=a straight angle.

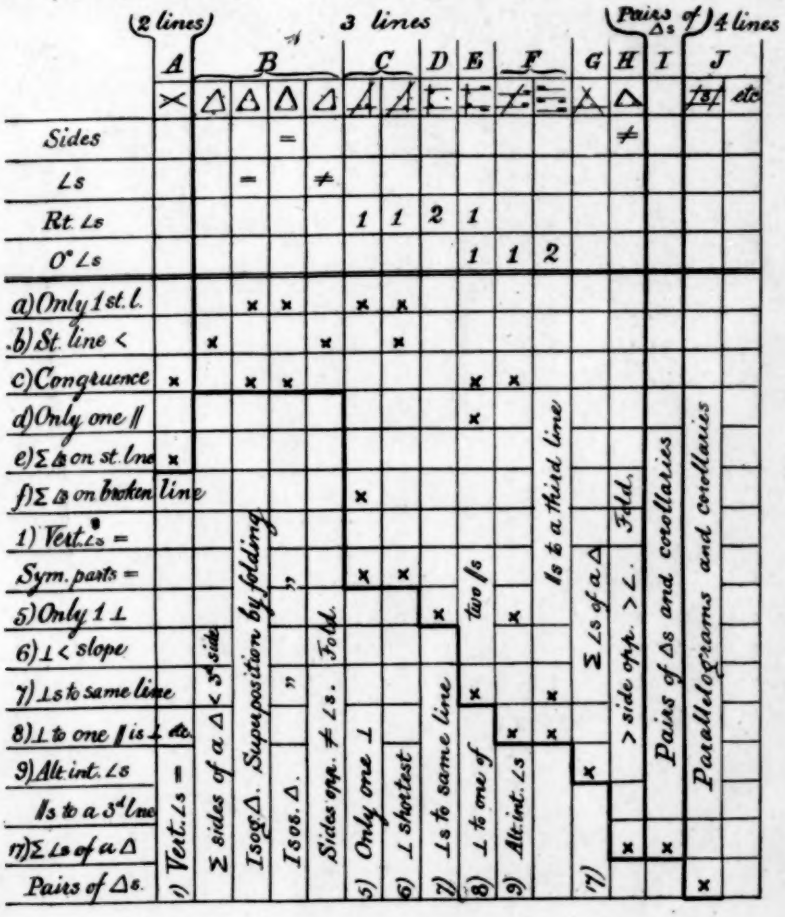
The looks of the diagram suggests the theorem.

(1) Vertical angles are equal

and the aspect of the plane suggests symmetry and the theorem.

(2) Symmetrical parts are equal

proved by the identification of axial symmetry as the property of fitting together in pairs when folded along the axis (see C).



A *third* line in the plane produces line segments, and a surface segment. To utilize this three-line figure, the most fertile course of procedure will be to give special values to the parts. Doing this and arranging the resulting phases (theorems) in the order in which the antecedent theorems are used, we get the sequence shown in the accompanying diagram, the small crosses indicating the theorems in the first column which are used in proving the theorems at the head of each column. In the small diagrams at the heads of the columns the elements of the hypothesis are marked heavy and the elements of the conclusion indicated by light dots. Each column is supposed to include the immediate corollaries of the indicated theorem.

Examination of this table of deductions will show the gradual advance, natural and suggestive, along a path of cumulative complexity, beginning with a simple 2-line, then a 3-line, pairs of 3-lines, then 4-lines, etc.; each step forward being closely supported by the propositions behind it, and each step forward being strongly suggested by some phase supplied by the initiative of the student as he varies the values of the different elements of the configuration.

The letters A, B, C,....indicate the rank of the propositions in the order of development.

If there is a natural line of development, a normal order of propositions, this seems to come pretty close to it.

The fourth proposition of B may belong between C and D, dependent upon the second of B; according to the rigor demanded. Its present position is hardly rigorous. Proposition H may use the third of B instead of folding.

Twenty states in the Union produced pig iron in 1905. The total production of pig iron in 1905 was 22,992,380 long tons. This is an increase in quantity of 6,495,347 long tons, or over 39 per cent, over the production of 1904. It is an increase in value from $233,025,000 to $382,450,000, amounting to $149,425,000, or 64.12 per cent. The average price per long ton of pig iron increased from $14.13 in 1904 to $16.63 in 1905.

A FEW DEFICIENCIES IN THE TEACHING OF MATHEMATICS.

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(CONTINUED FROM THE JANUARY NUMBER)

As has been said the great purpose for which mathematics exists is that of unsealing the mysteries of our physical surroundings and to give us control of our environment. The great problem for the teacher is to fit the pupil for this work of mastering his world by the use of mathematical methods. It is not sufficient that a man be able to demonstrate a set theorem or solve a given equation. Nature does not present her problems in that way. He must learn to form his own equations. He must learn to adapt means to ends. He must have power of initiative, and here is where we come upon the third deficiency in our instruction. I am inclined to think that unless this power, the proper means for overcoming difficulties, is trained in the pupil, the chief advantage of mathematical study is missed: the selection of the proper mathematical terms in which to express the problem precisely, and the proper mathematical devices by which to obtain from this precise statement the information desired. The student who pursues most texts seldom gets any inkling of the way in which the path was blazed, of why this detour was made, or of why that obstacle was avoided. He is told to do this and that and the reason is not pointed out. There is a vast difference between two reasons, the reason why a certain statement is true and the reason why it was made. But of this the student is left in ignorance and is led blindly on and so receives no training in the power to attack in the face of real difficulty. Now I think it is clear that a man can never learn how to use mathematical strategy unless he has studied the strategy of the victorious battlefield of mathematics, and yet it has been the practice of our texts to cover and hide the strategical. For instance in a certain operation in which a constant appears we are told to put it in a certain form for convenience and why, pray tell? It were better to leave the form unchanged until the desirability of a change is impressed and the advisability of a certain change perceived.

In our effort to make our demonstrations compact and elegant (?) in form we have polished off all the landmarks and cut down the guide posts that tell the way.

A good illustration suggests itself to me. When the method of decomposing a fraction into partial fractions is given, the student is told that the resulting fractions will have a certain form. But why that form rather than any other, the student cannot for the life of himself understand. It all seems artificial to him and he suspects some hocus-pocus about it. Whereas the way in which those forms are determined is rich with meaning and affords a deep insight into mathematical methods.

We have gotten into a sort of formal, juiceless way of dealing with the transformation of radicals and for the pupil it is but another pathless briar patch in which he is to stumble and prick his thumbs.

May I suggest that the reduction $\sqrt{50} = 5\sqrt{2}$ will come as a welcome relief after he has gone through the dreary computation of the value of

$\sqrt{50} + \sqrt{32} - \sqrt{18} + \sqrt{98} - \sqrt{162}$ by extracting the root of each term.

$7.0711 + 5.6569 - 4.2426 + 9.8995 - 12.7279$, and we find the simple $5\sqrt{2} + 4\sqrt{2} - 3\sqrt{2} + 7\sqrt{2} - 9\sqrt{2} = 4\sqrt{2} = 5.4568$. So too, lead him through the computation $\sqrt{6} - \sqrt{\frac{3}{8}} - \sqrt{\frac{3}{8}}$ to the quiet waters of $\sqrt{6} - \frac{1}{8}\sqrt{6} - \frac{1}{2}\sqrt{6} = \frac{1}{8}\sqrt{6} = .4083$ and again plunge him into $\sqrt{3}\sqrt{2} = 1.7321 \times 1.4142 = 2.4495$ where he uses 155 figures only to bring him to with $\sqrt{2}\sqrt{3} = \sqrt{6} = 2.4495$ in which he uses 65 figures and a little later into the use of logarithms where his result is found with 31 figures or finally the table itself where he needs but six figures.

After such a course the student begins to have some appreciation of that matchless characterization of mathematics due to Professor Maschke. "In mathematics we learn how not to do a thing." The object of reduction of forms is perceived as well as the correctness of the method. Now I believe that the whole realm of algebra can be treated in a similar dynamic way. Our books are for the most part cut and dried treatises on algebra rather than living guides through a wilderness where algebra can hew out the way.

Suffer me to offer another illustration from geometry. Let us take the triangle. The student finds set down certain theorems which he is told are true and which he may apply to carefully selected triangles. (Great care was taken in this sorting that no triangle was allowed to slip in save the selected kind.) That

certain ones are left out is never mentioned. In trigonometry the solution if the triangle is formally divided into cases and the methods given as though they had been found tacked onto the triangle when it was first discovered by man. The student finds a ready made classification but why and how it came about he could never tell. To go through a similar course he is unprepared.

May I suggest an extended investigation in some such manner as follows: We start with the actual construction, by compass and rule, of triangles and the possibility and non-possibility of construction with certain known parts. Sometimes a triangle can be constructed and sometimes not. When? Why? Equilateral, isoceles, scalene, right angled, come to light as facts. Theorem after theorem is developed and the theory is built up as far as we desire to go. Let us turn to the mensuration of a triangle. It is soon discovered that the kinds of triangles that can be completely solved, or partially so, by the use of ordinary geometry are very few indeed. This will never do. We must find out how to solve the others. The desire to do this can be intensified by the setting of actual problems in heights and distances of buildings and hills in the vicinity.

When the point has been reached where it seems that the way is blocked and no further advance is possible shift the attention which has up to this time been chiefly concerned with the sides of the triangle, shift the attention to the angles. The idea of the trigonometric ratios sine and cosine may now be developed experimentally by measuring the sides of a right angled triangle. This naturally comes in connection with similar triangles. A table of sines is constructed and it is soon seen that this new idea will help us to solve all right angled triangles. Proceed now to the isosceles triangle and then the scalene triangle remains to be conquered. This is a poser for a while. But use the same device that was used in the reduction of the isosceles triangle and the law of sines emerges. Apply this to all conceivable cases and its limitations are found and we are again compelled to renew the search. We now develop that up to this time useless theorem: In any triangle the square on the side opposite an acute angle equals the sum of the squares on the other two sides less twice the rectangle of either side and the projection of the other side on it; and the similar theorem for obtuse angles; and hence the law or cosines, and the problem is found to be solved.

It remains for the class in trigonometry to refine these methods by fitting them for logarithmic computation. In analytic geometry the question is reopened from a different standpoint and more powerful methods invented.

A certain series of investigations has been carried through a successful issue, each difficulty has been met and conquered as it came up. The student has been led with open eyes along a path directed to desired ends and he has been able to perceive the meaning of it all.

To my mind we should thus work in the open and take the student into our confidence. An understanding eye and a discriminating brain are as important as an efficient hand. The importance of mathematics in the every day work of the world has increased immensely in these days of engineering activity. It is the man who can answer unanswered problems that is the successful engineer or scientist today, as ever.

By seeing the path others have cut we can learn how to cut a path. This power of initiative fails to be developed often through our kindly intended yet nevertheless mistaken efforts to aid the student. We are rather inclined to do too much for him. We state his problems and leave him to follow and verify.

This change of emphasis, the filling in of this deficiency in our instruction, will necessarily cause some change in the material selected for consideration. How can we best adapt ourselves to these ideals?

Let me hazard this criterion: those subjects should be selected which are of the most importance and have the largest field of application. Usableness is the test. Not merely usefulness in the workaday world of bread and butter but usableness in the field of mathematics, science and engineering. As an illustration of what I mean, contrast the value, judged from this standpoint, of the theory of the magic square and the right angled triangle, the G. C. D. by division method and theory of exponents, the solution of a large number of triangles and a thorough knowledge of trigometrical functions and their transformations, cunningly contrived exercises which merely show how mathematics is not used and the exercises actually come upon in real investigation.

The properties of integers, fractions and roots are of constant use in mathematical study and should be so mastered that there can be no mistake in their use. I sometimes think that we fail

in trying to be so complete. A given idea will grow if once it be thoroughly planted in the mind of the pupil, just as a plant grows. We but waste time and effort in trying to get the full flower in a day. The idea back of a^0, a^3 will grow naturally from the theory of integral exponents, if not promoted. This power of insight and initiative will be developed, too, by allowing the student to correct his own mistakes. The check should be a common mathematical testing plant. But I have no time to pursue this line of thought.

What we need is time to develop in the mind of the pupil a sympathetic knowledge of the wide field in which mathematics can be applied even if time to do some useless thing is lost. Let him gain a vision of the grand edifice of mathematics even though he be not able to unravel some of the artificial labyrinths of the pedant and task master. Let him enter the mathematical work shop rather than as Beltram says, "make his mind sterile through the everlasting exercises which are of no use except to produce a new Arcadia where indolence is veiled under the form of useless activity."

California was the only state producing chromite during 1905. The quantity produced was 25 long tons, valued at $375, as compared with 123 long tons, valued at $1,845, in 1904, with 150 long tons, valued at $2,250, in 1903, with 315 long tons, valued at $4,567, in 1902, and with 368 long tons, valued at $5,790, in 1901.

The production of zinc in 1905 showed an increase in quantity as compared with 1904, 1903, 1902, and 1901, the production being 203,849 short tons, as compared with 186,702 short tons in 1904, with 159,219 short tons in 1903, with 156,927 short tons in 1902, and with 140,822 short tons in 1901. The value of the zinc production in 1905 was $24,054,182, as compared with $18,670,200 in 1904, with $16,717,995 in 1903, with $14,625,596 in 1902, and with $11,265,760 in 1901.

TROUBLE IN SOLID GEOMETRY.

By G. W. Greenwood.
Roanoke College, Salem, Virginia.

It is customary at the beginning of the subject of solid geometry to recall a definition of a plane. I doubt, however, if a plane can really be defined; but believe the conception of a plane is based directly on experience. A common so-called definition, that it is a surface such that a straight line through any two points of it lies entirely in the surface, is only a statement of a property which a plane—the mental picture of which must first be present in one's mind—is observed to possess. Other equally important properties, that there are points not in a plane and that a plane divides the points without it into two classes, are often passed over in silence, and surreptitiously assumed when needed. As a companion to the definition of a straight line that it is the shortest distance between two points, I would suggest, not seriously but only for comparison, that a plane is the smallest surface within a triangle. It can and should be shown that two planes having three non-collinear points in common are coincident.

A leading proposition is that "two *intersecting* planes *intersect* in a straight line," in which it is generally assumed that two planes with one common point have another common point; a fact which cannot be derived from the definition. Intersecting planes are left undefined.

The unfortunate custom of defining terms first and later proving the existence of figures having the assigned properties, is usually followed; for example, a perpendicular to a plane is first defined, with great redundancy, and the existence of a line and a plane with these properties is demonstrated afterward. In the demonstration it is assumed, however, that two intersecting lines have a common perpendicular—a fact not at all obvious. If anyone will furnish a demonstration independent of subsequent propositions the writer will be glad to receive it.

Parallel planes and a line parallel to a plane are also prematurely defined, and it would be well to *prove* that a line or a plane intersecting one of two parallel planes intersects the other. This property is, I believe, always assumed by authors.

In constructing a perpendicular to a given plane α from a given point P without it, we draw a line α in α, a perpendicular from P to x meeting it in a point A, a line y in x through A perpendicular to x, and finally a perpendicular from P to y meeting it in a point B. In showing that PB is the required perpendicular, authors speak of the *triangle* PAB, overlooking the fact that A and B may coincide; an emergency which deserves attention.

We all know what we mean by a closed surface. It is sometimes defined as a surface such that every plane section consists of one, or more, closed lines. Consider the surface of a coiled spring in the form of a helix and of unlimited extent in the direction of its axis. Every plane section would be one, or more, closed lines, the number being unlimited when the plane is parallel to the axis. Does the definition hold?

A prism is repeatedly defined as a solid, two of whose faces are parallel and congruent, and whose remaining faces are parallelograms. Some months after constructing a solid having these properties, a rhombohedron with twelve faces, parallel and congruent in pairs—that is, a twelve faced parallelopiped since its bases were parallelograms!—I saw a garnet crystal of the identical form I had devised; a solid refuting this definition had existed for ages. Doubtless all know how the hexagonal cell of a honey comb is closed by three congruent rhombuses. If we place the open ends of two cells together so that the faces closing one end are respectively parallel to those closing the other end, we have a solid satisfying the stated conditions. Is it a prism? Of course when we use the above definition all propositions in the subject of prisms are fallacious.

"Sections of a prism by parallel planes are congruent polygons."

Take, for example, a cube; a section of this prism by a plane intersecting internally three conterminous edges will be a triangle. The section by a parallel plane may be a triangle, a quadrilateral, a pentagon, or a hexagon; but evidently parallel sections are rarely congruent. In particular, four sections of a cube are regular hexagons.

We should obtain a good definition of a prismatic surface and then show that sections by parallel planes are congruent polygons.

In so doing, however, we should avoid the usual fallacy of showing these polygons to be mutually equilateral and equiangular and then following immediately with the statement that they must be congruent; for I have shown* that two polygons may be mutually equilateral and mutually equiangular without being congruent.

Some authors tell us that a right section of a prism (prismatic surface?) is the section made by a plane perpendicular to *all* the lateral edges. Are they careful lest we get it perpendicular to some of the lateral edges and not to the others?

"An oblique prism is equivalent to a right prism whose base is a right section of the oblique prism and whose altitude is equal to a lateral edge of the oblique prism."

The author usually supplies a figure in which the right section intersects all the lateral edges internally, and we see, literally, that the two prisms have one portion in common and the remaining portion of one is proven congruent to the remaining portion of the other. But suppose the given prism is so oblique that we cannot obtain a right section cutting all the lateral edges internally; the proof no longer holds.

Any demonstration which holds only under certain conditions must explicitly set forth those conditions or be open to the charge of fallacy.

Many other fallacies in solid geometry, including the use of such undefined terms as the area of a curved surface and the volume enclosed by a curved surface, are too obvious to be discussed. The treatment of limits and of incommensurable cases is not rigorous and probably never can be. But even the usual demonstration in the commensurable case that two rectangular parallelopipeds have the same ratio as the product of their three dimensions, is wholly unsound.

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*Notes on Geometry. School Science and Mathematics, May, 1905.

HINTS ON GEOMETRY TEACHING.

By G. C. Shutts.
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It goes without saying that in this country and in this day of geometry teaching that our aim in teaching geometry is to encourage the pupil to do the maximum of original demonstration and construction and to use any legitimate authority without regard to an arbitrary standard or text; that the standard of success for the pupil in a given demonstration is: "Have I given authority that we have already established or agreed upon for each claim that I have made from premise to conclusion?" When the pupil has acquired this power to select the proper authority and make accurate application of it, the function of the teacher is accomplished, for the pupil is self-directing and can master the subject by himself. He has in part acquired and is acquiring the mental power for which the subject is generally taught. All that follows in this discussion is based upon the above assumptions.

Probably the most difficult thing to accomplish in teaching geometry is to get the pupil in the habit of studying carefully to determine what is to be proved and what is given him in the theorem as a basis for the proof. In the assignment of the lessons in the early part of the course, it is well to have the pupils again and again select from the theorem this data. If the thing to be proved is indicated by a defined term, as parallelism of two lines or of two planes, a parallelogram, etc., the pupil should state what is to be proved in terms of the definition.

It is a common remark that the mathematics of the secondary school should be considered as a tool to be used in other subjects or in life. This, like many another, is but a partial truth. Each of the mathematical subjects becomes to the pupil who must terminate his school life with its completion, if it has been truly a thought study, a vital possession, a source of genuine pleasure, a means of acquiring conscious power. But these subjects to a certain extent are tools, and as tools they should be made as efficient as possible; and it is probably true, that the more it is appreciated that a given subject is a tool, and the more efficient it becomes as a means to a given end, the more truly will its other values be appreciated. Hence to get the fullest value in this line from geometry, each axiom, definition, theorem, etc.,

should, when once acquired, be regarded as an instrument with which to do further work; hence the more thoroughly it is mastered the more valuable it becomes. The pupil should be tested as to whether he can recognize the theorem in different relations; he should know the essentials from nonessentials; should be given opportunity to recognize it with many as well as with few nonessentials. A reason why pupils are so slow to use established truths in original work, is that they have seen their application in but one form usually lettered in the same way, or they have not brought it to bear in any way upon matters outside of the school room.

For instance, the isosceles triangle may never be expressed upon the blackboard with the vertex down or at the right or left of the base; it may never occur to the pupil that the corner of a sheet of paper, or hundreds of other things about him, is a representation of his notion of a right angle. If he be given a carpenter's square, or other right angle, and be asked to test its accuracy by the truth he has acquired, the value of the truth becomes at once more fully appreciated as well as the truth itself more fully known. When he has learned that two triangles are equal if two sides and the included angle of one are equal to two sides and the included angle of the other, respectively, if he be asked to apply it in finding the distance between two points that cannot be measured on the straight line between them, he feels that geometry is a part of life.

Let the value of a theorem be shown by using it in the demonstration or solution of exercises. When an exercise is proposed, let the pupil rehearse all the theorems that may refer to the topic in hand, and from them select one or more that are suitable for use. It may be profitable to make several solutions. For instance after several tests for a parallelogram have been proved let each one be used in establishing a new test that may be called for. Or when a third or fourth proportional is to be constructed, let the pupil rehearse all the theorems in which four terms are in proportion; let him study the figures involved and effect a construction by means of two or more of them. For instance, construct a fourth proportional to three lines by two chords intersecting in a circle; by constructing two similar triangles; by two parallel lines intersected by lines drawn through a common point; etc. A third proportional con be constructed by each fourth proportional proposition and also by each mean proportional

proposition; a mean proportional by each of the latter. By a large use of theorems as tools in construction, interest in the subject as well as the efficiency of the subject as a tool is enhanced.

In effecting constructions, as elsewhere, the pupils need to be taught how to study: One way to accomplish this, after agreeing upon a previous theorem for use as a tool, is to represent this theorem by a figure and study its properties, to see how it may be used in making the construction. For instance, suppose we wish to construct a third proportional, x, to lines a and b, the latter being the mean proportional, using the theorem that a perpendicular from the vertex of the right angle of a right triangle to the hypotenuse is a means proportional between the segment of the hypotenuse. When the general figure is drawn, ask such questions as: Where in the construction must b be found? Where is a? When will x be found? Which lines, a and b being given, can first be drawn? How are a and b related in the figure? Then by what authority can they be drawn? Which line can next be drawn? How is it related to a and b? Then how can it be drawn? Which line next? Authority for its construction? etc.

A grave difficulty in solid geometry in attempting to do original thinking, is in the use of authority from plane geometry. The pupils are apt to take the authority literally and forget that a common fact is assumed in all statements in plane geometry but not stated, viz.: that all the lines are in the same plane. Sometimes the authority to be used is of such a nature that the lines must lie in one plane, as the lines of a triangle or a line perpendicular to a line; in such cases no mistake can be made. But the lines of an authority may be in different planes if the above assumption is not insisted upon. For instance, the authority, "at a given point in a line one and but one perpendicular can be erected." If the pupil wishes to apply this theorem in an indirect demonstration, he is apt to forget that the two perpendicular lines and the assumed line must all be in the same plane, for any number of lines perpendicular to the same line at the same point are possible in solid geometry. Again, suppose the pupil wishes to prove that the intersections of a plane with two parallel planes are parallel lines. First, "What is to be proved?" "That the lines are parallel." "But when are lines parallel?" The pupil thinks of the definition, and says, "When the lines can never meet." This form of statement, true for plane geom-

etry, is not true for solid geometry. Hence the pupil in his demonstration must call attention to the fact that the lines in question are in the same plane, as well as that they can never meet, if he would do thoughtful and accurate work.

It is advisable to group in review all propositions having a common element; as, propositions on parallel lines and transversals, lines perpendicular to a line, tests for determining when a quadrilateral is a parellelogram, tests for determining that two triangles are equal, etc.

If the teacher is also the instructor in physics or engineering, etc., he can help the pupil to anticipate this subject by getting the geometric tools ready for use in it. But it is not wise to assume that this is the main function of geometry. A persistent application of parts of the subject in the development of other parts, with a wise selection of subject matter, together with a determined and courageous effort to limit the amount of matter to the time of the course and the ability of the pupil, will probably make the subject abundantly vindicate its demand for a place in the curriculum of our secondary schools.

THE TRAINING OF THE INDUSTRIAL CHEMIST.

By W. D. Richardson,

Chief Chemist, Swift & Company, Chicago.

My point of view is that of one who wishes to see the graduate in chemistry enter into his life's work well enough equipped to insure him a fair degree of success, without to great delay. Most persons recover but slowly from their first failure. Further I have in mind only the man or woman who can devote but four years to the work of preparation. I have nothing to say of the one who is free to spend seven or twelve years at a university. Of the difficult problems which confront our educators I am not at all qualified to speak, and I trust that nothing I have to say will offer insuperable pedagogical difficulties. I feel indeed somewhat apolegetic, that I should have the temerity to speak of education before educators, since I am in nowise a teacher. But I have come to believe that the schools and colleges and universities are not the only educational institutions. Are not the large industries of the country also educating large numbers of people from day to day? The methods are different, but the results have points of similarity. It is only because I feel that I too am

on the faculty of an educational institution that I presume to address you at all.

My first thought was to name my talk this afternoon "The Trade of Chemistry vs. the Trade of Bricklaying," for I could then tell you directly that the latter trade is as honorable, no harder and more remunerative that the former. The apprenticeship in the bicklayers trade lasts about four years. In the trade of chemistry in the work's laboratory about as long. The bricklayer earns from $25.00 to $35.00 per week, the journeyman chemist from $15.00 to $25.00.

But let me go back a step. It may not have occurred to you that there is a trade of chemistry as well as a profession of that name. I designate as a journeyman chemist one who as a young man spends a certain length of time in the laboratory of a manufacturing establishment, among trained chemists learning how to make routine analyses. In all large laboratories there are a number of such men working. They come from various ranks, as they would to learn any trade. The reason is that the monotony of routine work soon wearies and discourages a properly trained graduate and incapacitates him for the work he is better qualified to do. The making of thirty or forty nitrogen determinations daily, after the art is once well learned, does not require a great knowledge of chemistry, nor does it tend to develop the broadest kind of chemist. At the same time this sort of work requires all the skill and watchfulness the average man can muster. In every larie laboratory there is much work of this sort and it, as well as other work, must be handled.

There is nothing more illuminating to the college graduate than his entering a work's laboratory, there coming in contact with boys and young men who without any college training are making chemical analpses in the most approved way. He soon finds that it is only by the greatest endeavor and hard application on his part that he can compete in any degree with these employees. He discovers too to his chagrin that these men are naturally about as capable, about as clever and considerably more inured to continuous hard work than himself. His observations will at first discourage him in a large measure, but at the same time will lead him to inquire as to what particular merit his college training has conferred upon him, and in his answer to this question and his resultant action will lie in large degree the reason for his future success or failure. Moreover at this point the

kind of college training he has had will in a very great degree determine his answer. And if he has been led in that training to look in any narrow way upon chemistry, as though that science were no more than a collection of suick methods of analyses, I doubt not that he will very properly consider his time in college misspent. And more to this point still, his employer will agree with him. But this spells failure—temporarily at least.

I do not want to be understood as speaking slightingly of chemical analysis. The importance of analytical chemistry to the general science can hardly be overestimated or overstated. But there is a tendency in some colleges and universities to devote a large part of the student's time to highly specialized branches of technical analysis, such as iron and steel analysis, fertilizer analysis, sugar analysis, etc. I make this statement from my observation of the qualification of a number of young men, college graduates in chemistry employed every year. I have not examined the curricula of many institutions, nor do I consider this particularly necessary or enlightening. One who has to do with young men from college soon learns to know what to expect from the various institutions from which he receives graduates, in other words knows the institution by its works. And I can lay it down as fundamental that the one who is surest of success in so far as that depends on his college work, is he who has devoted his time mainly to a study of general chemistry and the principles of chemistry and not to iron and steel and other branches of technical analyses. I say iron and steel analyses as an illustration, for there are many other things which belong in the same list.

Now analyses must be taught, but how. Will not a few methods of general application, carefully studied, equip the student for the work before him better than many special methods, hastily covered? Remember, I am speaking of a four years' course, where selection and elimination are necessary. Again, special methods of all kinds, if learned at college, must be relearned in practice, for the methods used in various works are highly specialized and differ among themselves. So in studying a method at college, the principle after all is the important thing and strangely enough, the only thing which can be applied in outside work.

I have been speaking so far of work in the routine laboratory and most chemists on leaving college find their opening to the larger and more difficult fields through this gateway. But if

principles are the only part of a college course which can be applied in a routine laboratory, such as a steel works, an oil works, or a sugar works laboratory what shall I say of those most difficult fields of applied chemisty—engineering chemistry, legal chemistry, manufacturing chemistry and all positions where one is called upon for consultations of the most diverse and unexpected sorts? The most difficult of all branches of engineering chemistry is, I think, that dealing with the handling of gases on the large scale. Can you think of a young man undertaking such work with less than the best understanding of the gas laws, of combining volumes, of the relationship of temperature and pressure, of specific heats at high temperatures? And yet how many graduates in chemistry are even ordinarily well informed on these subjects, which are of such great and increasing importance in metallurgy, in sulphuric acid manufacture by both lead chamber and contact process, in soda manufacture and producer gas plants, not to mention that subject of more recent investigation the fixation of atmospheric nitrogen.

It is with considerable hesitancy that I mention one of the prominent, diseases shall I say? which affects the graduate who enters his life's work. It is the helplessness with which so many are afflicted. Ask one of these to obtain any information for you, or to examine a new or unusual product and the questions fairly stream from him. Some of these sound in my brain like the voice of Mrs. Caudle in Caudle's ears:

> **Where do you want me to look?**
> **Have you any references?**
> **What have you in mind?**
> **Is the method written out?**
> **What does Lunge say about it?**

I have seen illiterate boys with the barest education (who said they were sixteen but looked ten), who when sent in quest of anything would return with it if they had to move superintendents and general managers and upset all routine to get it, and they never asked questions. This inability to do, is not confined to young chemists but is apparent in other lines as well and therefore I should not dwell on it. Suffice it to say that the sufferer usually soon recovers from it in practical work. But why should he have the disease at all? Can not the commercial remedy—atmosphere, discipline or whatever it is—be applied in college and thus make the man whole before he begins his out-

side work? May we not look in the future for a closer affiliation between educators and commercial men. Each may learn from the other.

But I have no desire to dwell too long upon the dark picture of assured failure. There are young men who come to us from college who can discuss a new proposition concisely and intelligently, and who, without constant supervision and assistance, can work out a new method, and indeed suggest a change in manufacturing methods, which, if practiced, will not consume the last ten years' surplus earnings. Such men, I find, have been trained simply and broadly in the field of General Chemistry in the theory and principles of chemistry, and their practice in the laboratory has been general. Such men rise rapidly, other things being equal. They inspire confidence. One can trust them to do things directly and without disproportionate consumption of time. And there are many institutions to-day—but not all—who turn out only men of this kind. When we have such suggestive works at hand as Ostwald's "Conversations" and Smith's "General Chemistry," why should not all graduates be chemists in the best sense?

A man at college can never tell just where he will bring up. And again for this reason great attention to technical detail should not be shown. There is too much building of miniature factories in colleges. It is well enough to learn the principles of dyeing but it is a waste of his precious time to teach a student of chemistry the dyer's trade. That he can learn better by entering the factory. We have too many journeyman-chemists, too few chemists, too many chemical tradesmen, too few with the broad outlook which should appertain to the profession. And so I come again to my original proposition, do not train chemists for the trade of chemistry in school, college or university, although in the trade of chemistry there is good and honorable work—better advise them to take up the trade of bricklaying—work equally honorable and more remunerative with better hours. If a man insists on learning the trade and not the profession of chemistry, send him to the nearest works laboratory and do not waste his time in college or university.

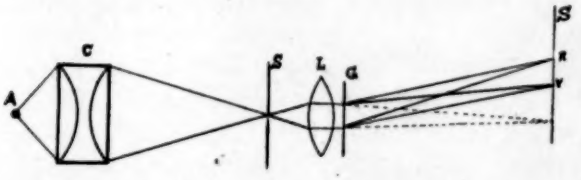
A LECTURE TABLE EXPERIMENT IN SPECTRA.

By C. M. Westcott,

High School, Redlands, California.

Recently, while showing bright line and continuous spectra with projection apparatus, I came by accident upon an interesting fact which may not be generally known to teachers of physics.

It is possible by the simple manipulation of the carbons of a single straight angle arc to show three types of spectra, viz., continuous, bright line, and dark line.



Sodium on account of its persistence was used for the line spectra. The projection lenses were removed from the lantern, and a narrow adjustable slit substituted. The arc was moved up as close as convenient to the condensers, and the slit placed at the conjugate focus. In front of the slit was placed a convex lens in such a position as to give a clear sharp image of the slit on the screen. A semi-transparent screen of tracing cloth between the lantern and the class was found to give the best results. A diffraction grating was used for dispersion and was placed just beyond the lens. The carbons while cold were dipped into a saturated solution of sodium chloride. If the carbons thus prepared are brought together and then separated for a very short distance, the arc formed will be surrounded by a sufficient atmosphere of relatively cold sodium vapor to absorb the energy of the characteristic sodium yellow from the white light of the arc and a well defined dark line will appear in the place occupied by the yellow lines of the sodium.

If the carbons be separated a little further, the whole spectrum becomes brighter, the dark line disappears, and we have a continuous spectrum.

If the carbons be now separated so far that little or no light from them is brought to a focus on the slit, the continuous spectrum will give place to the characteristic bright line spectrum of sodium.

A SIMPLE HYPSOMETER.

By E. N. Trauseau,

Station for Experimental Evolution, Cold Spring Harbor, L. I.

While conducting a course in forest botany at Alma College, Michigan, it became desirable to obtain measurements of the size attained by various species of trees, and also to make a topographic map of a tract of about sixty acres of timberland, for a detailed study of the variation in forest composition as related to topography.

The hypsometers catalogued by instrument manufacturers were found to be too expensive to supply to individual members of the class, so the following simple instrument was devised and found to be convenient and sufficiently accurate for the work. The principle involved is the same as that of "Faustman's Height Measure" described in Bulletin 36 of the U. S. Forest Service. Prof. Roth of the Michigan Forestry School has been using one, which differs only in its more elaborate construction.

CONSTRUCTION.

A rectangular piece of white pine 12×24×1 cm. forms the body of the instrument. Its upper edge is used for sighting and it supports the scale. The scale is drawn upon a strip of paper 12×24 cm. and pasted to the rectangular block. The board and scale are then covered with a thin coating of paraffin to render them waterproof and prevent warping. For the work in hand, a distance of 100 ft. between the observer and the object was found most convenient, so 100 ft. was made the basis of the scale.

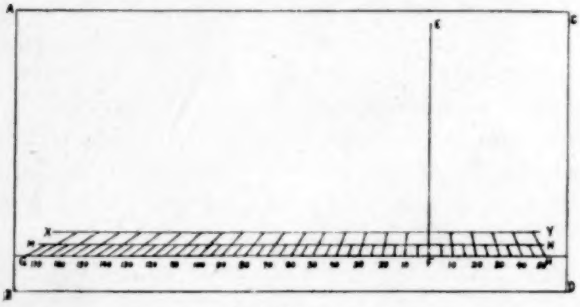


FIG. 1.

Figure 1 shows the construction of the scale. The base line GH is drawn parallel to, and 10.5 cm. from the side AC. Six centimeters from the edge CD a line EF, 10 cm. long, is drawn

perpendicular to GH. From the point F five millimeter spaces are marked off on GH in each direction. Two other lines XY and MN are drawn parallel with GH at distances of 10 and 5 mm. respectively. The alternate points on the GH line are then numbered according to their distance in millimeters from the zero point F (10, 20, 30, etc.). From these points lines are produced toward E, to meet the line XY. The intermediate points are connected in the same way with MN. Since all measurements are to be made at a distance of 100 ft. from the object, and the line EF is 100 mm. long, each millimeter space on the base line corresponds to 1 foot in the vertical height of the object The scale, as drawn, is therefore capable of measuring elevations 175 ft. above the level of the observer's eye and 50 ft. below. If the figures on the scale are printed reversed (as seen in a mirror) they are more easily read.

In order to read the scale while the eye is sighting the extreme of the object along the line AC, a mirror consisting of an extra-heavy tin plate is attached to the wooden block near the end CD. The tin plate is 24×10.2 cm. and the one end is bent around a wire 2 mm. in diameter and about 15 mm. long. At this stage in the construction the wire should extend beyond the edge of the tin plate only on one side. Two screw eyes having an eye diameter of about 2 mm. are then inserted in the wooden block, 1 cm. from CD and 10.3 cm. apart. The wire of the tin plate is

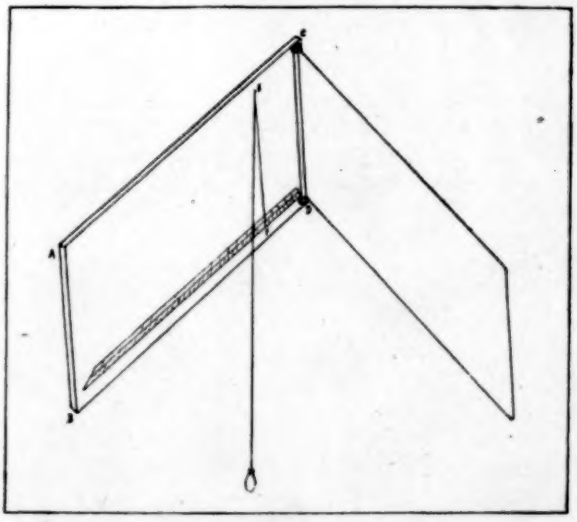


FIG. 2.

forced into the two screw eyes and the wire cut off flush with the screw eyes. This allows the mirror to rotate about an axis parallel with the line EF. A red silk string 22 cm. long, having at one end a rather heavy lead bob, is attached at the point E. Red is used as it contrasts well with the black lines of the scale. Figure 2 shows the complete instrument.

MEASURING THE HEIGHT OF TREES.

In using the hypsometer to measure the height of trees it is essential to have either a 100 ft. tape or better a 100 ft. piece of paraffine sash cord. Two persons are required, one to carry the end of the line to the tree, the other to hold the opposite end of the line and make the measurements. Since the instrument is held several feet above the ground at the eye of the observer, and because the ground is rarely level, it is necessary to make two readings, first pointing the hypsometer (line AC) to the top of the tree, and then to its base. In Figure 3 the eye of the observer is at E and on sighting the point A, the plumb line indicates on the scale the height of the point A above the level of the eye (EC). On sighting B the instrument is tilted forward so that the plumb line hangs on the opposite side of the perpendicular, and indicates the distance of the point B below EC. Obviously, the height of the tree is sum of the two numbers. If the observer stands below the level of B, both numbers are indicated on the same side of the perpendicular and the height of the tree equals the difference between the two measurements.

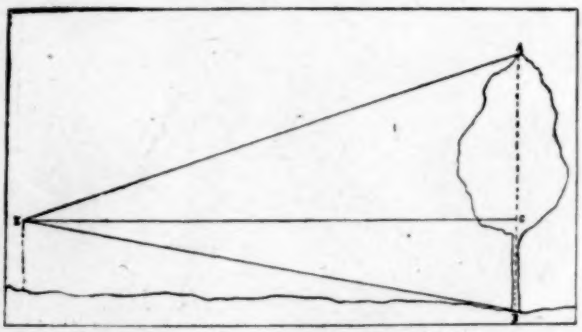


FIG. 3.

Where data in addition to height are desired it is convenient to have the person at the tree end of the line measure the diameter, identify the species and keep all the records.

TOPOGRAPHIC SURVEYING.

In topographic map making, it is necessary to divide the tract into hundred foot squares, with a staff compass and tape. Stakes are driven at each corner of a square. Some convenient point, preferably one whose elevation above sea level is known, is then taken as the base point and all height measurements are made with reference to it. Two persons are again required, one to read the hypsometer, the other to carry a staff having a target (such as a handkerchief) fastened at the same height above the ground as the observer's eye. When the staff is held at station B, the observer at station A records the relative height of the target as indicated by the hypsometer, using + and — signs to denote height above or below his own level. Assuming that station C is on the same line with A and B, its elevation will be measured from B and recorded in the same way. As soon as the relative measurement is made, the absolute height should be calculated and marked at the proper corner on the outline map carried by the observer. For example, station A is 870 ft. above sea level. Station B has a relative height of +8. This should be recorded on the map as 878 ft. Station C has a relative height from station B of —10 This should be recorded as 868 ft.

By changing the scale, the instruments may be readily adapted to the metric system and to the measurement of larger or smaller objects, at greater or less distances. The addition of sights to the side AC increases the accuracy of the readings.

The coke production of the United States in 1905, which included the output from 3,159 retort or by-product ovens, amounted to 32,231,129 short tons, as compared with 23,661,106 short tons in 1904. The increase in quantity in 1905 from 1904 was 8,570,023 short tons, or 36.22 per cent. The total value was $72,476,196, as against $46,144,941 in 1904, a gain of $26,331,255, or 57 per cent. The average price per ton in 1905 was $2.25 against $1.95 in 1904. The average output from the by-product ovens in 1905 was 1,158.8 tons per oven, against an average of 365.8 tons per oven from the beehive ovens.

NEW APPARATUS.

By Thomas B. Freas.

Kent Chemical Laboratory, the University of Chicago.

DISSOLVING TUBE.

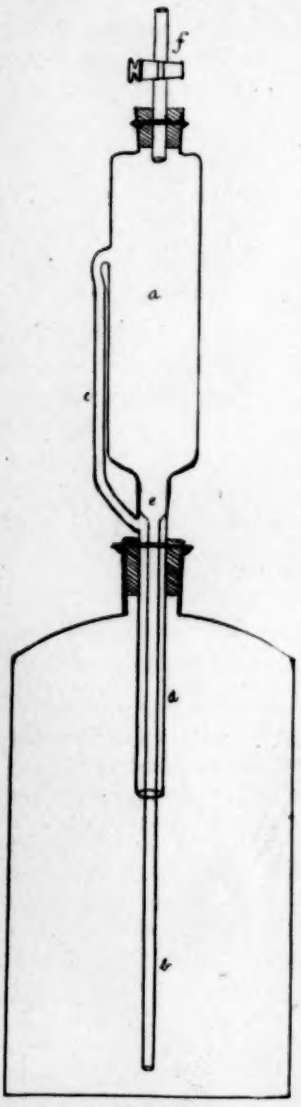


Fig. 1.

This apparatus (Fig. 1) is designed for dissolving solids which are difficultly soluble without the aid of heat or mechanical agitation, and filtering the solution at the same time. The tube as shown in drawing consists of a cylindrical tube (a) for containing the solid. From the bottom of this a tube is attached which is of proper length to reach to bottom of bottles in which the stock solutions are contained. From the side near the top a side tube (c) is joined which connects with the tube (d), which is a short extension of (a) and forms a jacket for (b). The apparatus has at (e) a cavity for holding a plug of cotton or asbestos wool for filtering.

The dissolving tube is held by a rubber stopper which has an air vent cut on the side. The bottle is filled with water and the proper amount of crystals are placed in (a), a plug of cotton or asbestos wool having previously been packed in (e). A suction by pump or the mouth is applied at a stopcock (f) in a light rubber stopper and the liquid from the bottle is drawn to fill (a) over the crystals. The stopcock (f) is now closed. The solution immediately travels down tube (b) because of its greater specific gravity and the water being lighter travels upwards through side tube (c). This will continue until all the crystals are dissolved or until the solution becomes saturated. The cotton or asbestos

plug serves to catch any sediment which may occur with the crystals.

Those laboratories which keep up stock solutions for general use find that there is no little labor in preparing these. Copper sulphate and potassium bichromate, etc., must be heated in an evaporating dish or agitated by shaking frequently in order to cause solution. By means of a tube of the above description a bottle of a solution of the strength ordinarily used may be prepared with little labor by allowing to stand a few hours.

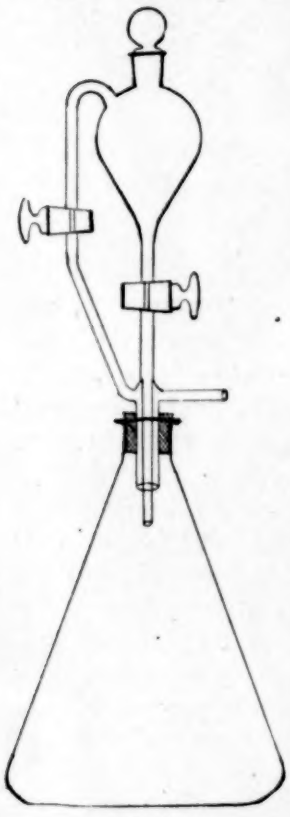


FIG. 2.

DROPPING GENERATOR.

The drawing (Fig. 2) will show readily how the apparatus is constructed. It may be used for dropping some liquid upon a solid or liquid contained in the Erlenmeyer flask, in order to generate some particular gas. With the ordinary dropping funnel difficulty is nearly always met in obtaining pressure enough to force the gas through the wash bottles and further train used in the operation. With this apparatus the pressure of the flask below is transmitted to the dropping funnel above. The stopcock at side is intended to prevent escape of gas if refilling the dropping funnel bulb should become necessary. This cock may be omitted very satisfactorily. Where a solid is used in lower Erlenmeyer flask it is desirable to have it in the form of paste if possible, especially if it be necessary to heat the Erlenmeyer flask. The heating should be done with a very small flame. The apparatus is very quickly set up and one will be found convenient for generating many gases. The following may be prepared with this generator very readily:

CO_2—HCl (dil.)+$NaHCO_3$

O_2—H_2O+[Oxone (fused Na_2O_2)]

H_2S—HCl (dil.) +[FeS (Powd)]

H_2—HCl (dil.) +[zinc (dust)]

NO—$NaNO_2$ (sat.) +[HCl (dil.)+$FeCl_2$]+heat

N_2—$NaNo_2$ (sat.) +[NH_4Cl+H_2O] +heat.

SO_2—HCl (dil.) +Na H SO_3

Cl_2—HCl (conc.) +$KMnO_4$+heat

HCl—H_2SO_4 (conc.) +NH_4Cl

C_2H_2—H_2O+Ca C_2

C_2H_4—[C_2H_5OH (absolute)]+H_3PO_4 (173)

H Br—Br_2 [(red) P +H_2O]

HI—H_2O+[P (red) + (Powd.) I]

The first chemical in each of the above list used for generating the gas should be in the dropping funnel and those following should be in the Erlenmeyer flask. It will often be found desirable to use this apparatus for generation of CO_2, H_2 and H_2S in preference to the ordinary Kipp apparatus. For lecture work a Kipp has the great disadvantage that one is unable to know whether it may not become exhausted during the time for the lecture. Consequently rather than take chances a Kipp should be refilled very frequently with much loss of good acid.

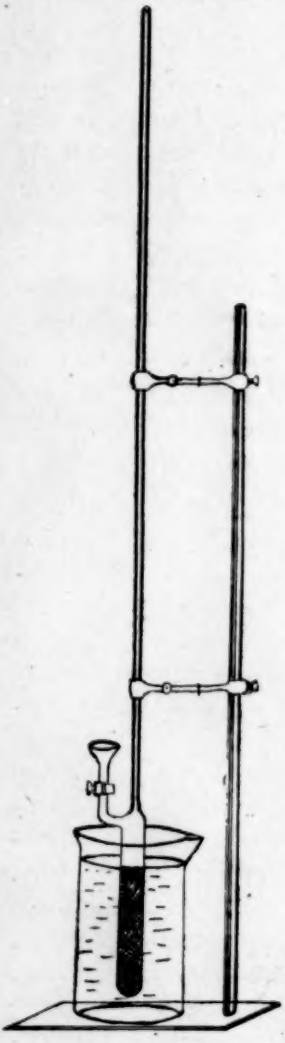


FIG. 3.

OSMOTIC PRESSURE TUBE.

This tube (Fig. 3) is made from barometer tubing about five feet long, with an enlargement and stopcock as shown by drawing. A parchment tube made by Carl Schleicher and Shull (No. 579 Diffusion Hulsen size 100x16 mm.) is fastened on the lower end. This may be made tight to the glass by applying a soft wax or a stopcock grease on ends of both parchment and glass tube and tying after many turns by strong linen thread; and then by means of a cork borer slightly larger than either tube, a short rubber tube may be stretched over the joint. The rubber tube should be stretched over the cork borer (or a simi-

lar brass or glass tube); then with safety it may be brought over the parchment tube and slipped from the cork borer onto the junction of this tube with the glass. When this is done a leak is very improbable, even though the solution may run over the top of the barometer tubing. By means of the stopcock a strong sugar solution, which has been colored by some red dye, may be introduced. The parchment tube then being placed in water in a beaker, the sugar solution will rise rapidly owing to the small bore of the barometer tubing, and the large surface of the parchment. The barometer tubing however magnifies the bore and the red solution may be observed at a distance by a large class. By allowing the parchment tube, after rinsing out sugar solution, to stand in a bottle of water, the whole apparatus may be kept intact and ready for use for a long time. The first one made did not need the parchment tube renewed for eighteen months and was used probably on the average once per month. This makes very easy a lecture experiment, otherwise difficult because of trouble of preparation and danger of leaks.

The total production of crude petroleum in the United States in 1905 was 134,717,580 barrels, as against 117,080,960 barrels in 1904, 100,461,337 barrels in 1903, 88,766,916 barrels in 1902, and 69,389,194 barrels in 1901, an increase of 17,636,620 barrels, or 15 per cent over the production of 1904, and of about 34 per cent over that of 1903.

The increase in 1904 came from Kansas and Indian Territory, and Oklahoma, Louisiana, Texas, California, Kentucky and Tennessee, and Illinois, in the order named. In round numbers, the gains in 1905 over 1904 were as follows: Kansas and Indian Territory and Oklahoma, 6,395,000 barrels; Louisiana, 5,950,000 barrels; Texas, 5,890,000 barrels; Kentucky and Tennessee, 219,000 barrels; and Illinois, 181,000 barrels. The largest decreases in production in 1905, as compared with 1904, were in Ohio, which showed a decrease of about 2,529,000 barrels; West Virginia, 1,066,000 barrels; Pennsylvania, 688,000 barrels; Indiana, 374,000 barrels; and Colorado, 125,000 barrels. It will be observed that the greatest gains were in the South and West, and that, relatively, the Appalachian field lost heavily.

The value of crude petroleum produced during 1905 was $84,157,399, or an average price of 62.47 cents a barrel, as against $101,175,455, or 86.41 cents a barrel in 1904, as against $94,694,050, or 94.26 cents a barrel in 1903.—*U. S. Geol. Survey Bulletin 260.*

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*All of the above glass apparatus may be secured from W. J. Boehm, glass blower, 171 Randolph Street, Chicago, Illinois.

STANDARDS IN SCIENCE TEACHING.

By Franklin T. Jones.
University School, Cleveland.

The standard each teacher sets for himself and his pupils is necessarily a local one—reasonable under the conditions under which the work is done. This paper has to do with some of the standards and devices for enforcing them which have proved useful in my own teaching and with some general principles which could be successfully applied and would result in much greater uniformity in science teaching.

My pupils must be prepared for the examinations for Harvard, Mass., Inst. of Technology, Yale, Princeton and Case School of Applied Science, and I have been compelled to study their requirements as illustrated in past examinations very carefully. At the beginning I had the same distrust of the fairness of the questions which is shared by most teachers who have not studied them systematically. It is true that every now and then unreasonable questions slip in but, on the whole, the questions are fair and not too difficult. In a surprising way they pick out and emphasize the real fundamentals of the subjects covered.

I have cut up old papers and mounted the individual questions on cards which have been classified and arranged as a card catalog. In the course of the year each student works through the list, if possible three times—once as the subject first comes up in the year's work, once again in the review at the end of the year, and out of this list I have selected about 300 problems and questions in physics and about 200 in chemistry which I use as a final review to clinch not only the facts of the subject but also to emphasize the fundamentals which every pupil understands he must know. The fact that the questions are from bona fide examination papers compels a respect which the ordinary problem rarely receives; then too a student takes greater pride in producing satisfactory answers to such questions because he believes in the college examinations as setting a high standard.

The effect of such a standard upon the teacher is very marked. He is compelled to work out the important points with great care and almost instinctively gives to the less important their proper emphasis. He differentiates between the essentials and those things which are only introductory to the essentials in a way of which he never before dreamed. The economy of time

is tremendous, amounting to fully one-fourth in the course of a year. Formerly I used to get one month at the most for reviews at the end of the year. Last year (1905-6) I had two months in physics and three in chemistry. This year I hope for about three months in each subject.

This time may seem disproportionate for review but a trial will prove the wisdom of the practice. More real learning will be done in the last two months than in the whole preceding work of the year. A many-sided review is an essential point in the maintenance of a high standard. I aim to cover the whole subject three times in the review—once from the historical point of view immediately following the completion of the advance work. At that time the student can see a man's discoveries in their relation to the whole subject and understand him as he could not earlier—once by questions for definitions, laws and principles in physics, and in addition for equations in chemistry; the third time by means of college examination questions and problems.

If any student has honestly gone through such a course, one need have little anxiety about his knowing the subject so thoroughly that he is ready for any examination, not because he has been crammed for the occasion but because he has mastered the subject.

We hear complaints from the colleges about the preparation we give our students. They are primarily to blame by not setting the standard at the proper quality of work. The quantity demanded is in most cases unattainable without sacrifice of quality. If all the colleges in the country would require entrance examinations of a reasonable kind—and, in the sciences, the examinations of Harvard, M. I. T., Case, Yale, Princeton and the College Entrance Examination Board are not unreasonable—we need be far less concerned over our standards in science teaching.

An immediate objection to a standard thus set by examination is that our teaching will degenerate into cramming our pupils for the satisfactory answering of the examination questions. If the average set of questions as asked by Sheffield Scientific School or Princeton in physics or chemistry is taken as the list for which preparation is to be made, cramming will result in an immediate improvement in the efficiency of our instruction approximating 25 per cent.

To those who make a study of the questions the reasons for improvement will become at once apparent. Fundamental things

are asked for and real preparation for such questions will necessitate a thorough mastery of basic principles—not only an understanding of them but the ability to express them in clear, concise, accurate English. This ability can be acquired only by practice. In my own teaching I find great difficulty in getting satisfactory written answers on simple fundamentals like the parallelogram of forces and its applications even though they are harped upon from beginning to end of the year. I believe the solution of the difficulty lies in repetition—in frequent rewriting of the answers to questions which involve these principles.

An essential in the enforcement of a high standard is the avoidance of too difficult questions and problems early in the year's work. The main reason for the almost universal repugnance with which physics is regarded is the unattractive way in which the subject is as universally introduced. Any subject which necessitates hard study and prolonged and consistent effort must be carefully handled at the outset so as to prevent the development of prejudice and the consequent excuse that it is too difficult for the average student. The preliminary steps in chemistry may be taken rapidly but the opposite is true in physics. I doubt if the first ten lessons in physics can be made too easy. Each pupil must be convinced that he not only can but almost likes to do the work prescribed and, as the course progresses, no precautions are too great to make sure that he solves all the easy problems given. From simple beginnings the teacher can work up the ability of his pupils to the point where even the difficult problems from the college examinations are possible. The critical point is never to impose a task that the pupil with reasonable effort cannot perform—to encourage by the consciousness of growing ability, not to discourage by assigning work that the pupil can not be expected to do—and finally to insist upon the satisfactory completion of the lessons given.

Another objection to be raised is that questions of the kind proposed will make our work mechanical and tend further to impair that "human-interest" about which so much has recently been written. I think it is sufficient to call attention to the fact that the humanizing of any subject depends, as we can all testify, not upon text-book nor syllabus nor method but upon the teacher. In his power lies the vitalization or devitalization of the subject taught.

In spite of these objections my proposal is as follows:—

(1) To make use of the College Entrance Examinations as Standards in Science Teaching.

(2) To economize time by concentration of effort on fundamentals so that two to three months of each year may be spent in a many-sided review.

(3) To require answers to questions on the fundamentals repeatedly written in clear, concise, accurate English.

(4) To make the introductory lessons, in physics especially, very easy. To cultivate power by gradually increasing their difficulty. This amounts to a sliding standard, low but thorough at the beginning of the year and severe and high at the end—the ability to give satisfactory answers to such questions as are asked at the college examinations.

A COURSE IN ELECTRICAL ENGINEERING FOR TEACHERS OF PHYSICS IN SECONDARY SCHOOLS.

By George A. Cowen,

West Roxbury High School, Boston.

There has been in progress during the current year at the Massachusetts Institute of Technology a course in Electrical Engineering and Testing provided by the trustees of the Lowell Institute in connection with its Teachers' School of Science.

The desire and plans for the course originated in the Eastern Association of Physics Teachers. It was designed to meet the needs of the members of that association although it was thrown open to all other teachers qualified to do the work. Until this time there had been almost no opportunity for teachers in secondary schools to do any advanced work in physics under expert supervision. Courses were open with the regular students at some of the near by educational institutions, but the lectures came on other days than Saturday so that the work be undertaken only by a favored few living within a short radius.

There were fifteen lectures, five upon the construction, use and calibration of electrical measuring instruments and ten devoted to a discussion of dynamo electric machnery. The lectures were followed by fifteen laboratory exercises, five in the standardizing and ten in the engineering department. The laboratory was open for three hours on each Saturday afternoon.

Five out of the following list were done by each in the standardizing laboratory: Wheatstone bridge, conductivity, Poggendorf method, voltmeter calibration, ammeter calibration, potentio meter, direct current wattmeter, insulation resistance, capacity, cable test.

In the engineering department the list of exercises was as follows:

Shunt motor, its efficiency and the ordinary motor curves; series motor, efficiency and curves; differential motor; Stray power method; characteristics of a series generator; shunt and compound motor; methods of speed variations of a shunt motor; shunt generators in parallel; incandescent light photometry; dynamotor.

Prof. H. E. Clifford, the head of the engineering department, was in charge of the course and delivered two of the lectures. The remainder of the work was done by assistant Professors T. A. Laws, H. W. Smith, and R. R. Lawrence.

Forty-nine registered in the course. Of these seven attended the lectures only. The average attendance at the lectures was about forty. In the laboratory section there were six who dropped out before the work was completed. Seven of those completing the work were young women. A fair idea of the interest taken in the course may be obtained by noticing the distances many of the teachers traveled in order to be present. Seventeen lived in Boston; nineteen came from a distance of about ten miles; six came twenty-five miles, and seven came forty miles.

The course was absolutely free, the expense having been provided by the trustees of the Lowell Institute. Had it not been free the cost per member would have been not far from $25.00. Teachers in this part of the country are not overpaid, so it is possible that a fee of $25.00 even would have prevented those living at a distance from taking the course.

Forty-four have already signified their desire to supplement this work by a course on alternating currents next year. The demand shows the success of the present undertaking.

This bringing together weekly the most progressive teachers of Physics in Eastern Massachusetts must of necessity unify, enrich, and raise the standard of the work in this department of science.

It seems to be a plan capable of being followed in any center having a college or technical school.

TWO INTERESTING PHYSICS EXPERIMENTS.

By Frank M. Greenlaw,

Rogers High School, Newport, R. I.

The following experiment has been used by the writer for several years to make visible to classes the reduction of temperature of a gas through expansion, as well as the lowering of the boiling point under diminished pressure.

A flask partly full of water is closed with a two hole rubber stopper, through one opening a chemical thermometer is passed, through the other a short piece of bent tubing over which is slipped a short length of rubber tubing and a Mahr Pinchcock. The flask is heated to boiling and when the air has been displaced the flask is removed and the pinchcock closed. Now instead of cooling the flask by dropping water on it, as is usually done, it is connected to a second flask from which the air has been exhausted as thoroughly as possible, and communication between the two is established by releasing the pinchcock. The reduction of pressure not only produces rapid ebullition in the flask containing water but cools the expanding water vapor to such an extent that the exhausted flask becomes filled with a dense fog.

The writer has also prepared magnetic field slides, for lantern use as follows:

An ordinary lantern slide cover glass is coated with a thin film of paraffine and the field mapped with iron filings upon this film in the usual way. The plate is then passed through a bunsen flame to soften the paraffine and "fix" the filings—and in a moment or two the plate has cooled sufficiently to use in the lantern. If bound with a fairly thick mat a very permanent and effective slide results.

The aggregate value of all the products obtained from the distillation of coal in gas works and retort ovens in 1905 was $56,684,972, as against $51,157,736 in 1904 and $47,830,600 in 1903.

The value of the natural gas produced in 1905 was $41,562,855, as compared with $38,496,760 in 1904, with $35,807,860 in 1903, with $30,867,863 in 1902, with $27,066,077 in 1901, and with $23,698,674 in 1900—a gain of about 8 per cent in 1905 over 1904.

THE POINT OF VIEW IN CHEMISTRY.

By Alexander Smith,
University of Chicago.

In an important sense it is not the particular selection of topics that determines the real value of a course in chemistry, but the point of view of the teacher who presents them. Yet, although all-pervading and all-important, this point of view is of all things the most difficult to define or describe. It may be felt in every word uttered in the class room, but is itself almost impossible of capture and of crystallization in words. We may seize some of its characteristics best, perhaps, by dipping into the teacher's version of the science here and there, taking a few samples and considering the mode of their treatment. The choice of samples may be determined by noting the points on which authors differ and the points in regard to which one's own views have changed; consideration of the points where there is a diversity of views and where changes in view have occurred should give some indication of the deeper seated, fundamental ideas whose influence determines the choice or suggests the change.

Let us take, first, the question, What principle is most fundamental in all chemical work; what fact is the basis of our performance and interpretation of every chemical experiment? Is it the atomic hypothesis? Many chemists used to think so, and some chemists still think so. In a recent text-book the most of the first chapter is devoted to a discussion of the minute subdivisions of matter and of the conceptions arising from a consideration of this subdivision. The treatment is logical, and satisfactory from the point of view that this is the fundamental idea at the basis of chemical thought and work. But, after all, does the chemist in point of fact carry on his work by considerations of this kind? Are there not facts about *masses of material* which are more continually in his thought? Would not a man who had encountered animal matter only at meal times in a Chinese restaurant have a rather distorted idea of the nature and structure of fish, flesh, and fowl, and does not the reduction of the carcass to chop suey obliterate or obscure some facts of large significance in Zoology? And does not, in the same way, a premature consideration of an imaginary process of utter disintegration withdraw the attention from the common aspects of chemical behavior as it really appears? The answer, of course, depends on one's point of view.

What, then should demand our attention, before the pulverization begins? Is it the principle of definite proportions? Does not this presuppose the conception of compounds and is not therefore the idea of elements and compounds more fundamental? Is this then itself the fact of which we are in search, the fact which is at the basis of all chemical work? But how do we recognize a compound? Is it not by obtaining from the compound two or more substances, with properties which distinguish them from one another and from the parent substance? Is not the basis, then, of chemical work the fact that each substance has its own set of specific, physical properties by means of which the substance is recognized and by use of which the substance is separated from other substances when necessary? In the point of view with which at present I sympathize, it is. And this particular view must have a large influence on the way in which emphasis is placed in doing and discussing chemical experiments. It at once puts in the foreground, as the object of every experiment, the observation of physical phenomena and the discussion of the observations in terms of physical realities.

Let us now turn to another subject, the treatment of which may give indications of the point of view. The atomic hypothesis has already been mentioned. At what stage may this hypothesis most usefully be introduced? The answer is found by asking, what fact in chemistry was it primarily devised to explain? Was it not the fact that the proportions by weight in which a given element enters into all sorts of combinations may always be expressed by a fixed number, or by whole multiples of this fixed number? The sypothesis comes in, then, when combining proportions by weight are discussed. In other words, the hypothesis is used in explaining the quantitative laws of chemical combination. May it be used at an earlier stage, for example, to explain the *fact* of chemical combination and the qualitative features associated with it? Does it clear up the mystery of the properties peculiar to cupric sulphide to say that a little piece of copper, "which has all the properties of a large quantity of the substance," when stuck to a little piece of sulphur, will give a little aggregate whose properties will be absolutely unrelated to those of the constituent atoms? Would not even a child see that the properties of a mass composed of the aggregates ought to be the average of those of two masses composed, respectively, of the pieces of copper and the pieces of sulphur? And if the

child realized that this notion—that the approximation of little pieces of different materials gives aggregates with entirely new properties—was a product of the imagination and simply an invention devised to explain the changes in properties, while the change itself was a fact, would he not tell you that your fairy story, regarded as an explanation of the fact, was a singularly complete misfit? As for the fact of combination itself, is not the cohesion of the particles of one substance individually with those of another just as difficult to conceive as the combination of the materials as wholes? In short, does the atomic hypothesis as commonly given, adequately explain the nature of the tendency to combine (affinity), or the mode of the combination, or the new properties of the product of combination, or the heat developed during the process of combination, or, indeed, anything, save the possession by each element of an individual unit of weight which it employs in all its combinations and, at a much later stage, however, some features in the chemical behavior of complex substances? And if we invite beginners to believe as a fact that diverse atoms are united into pairs, and that the properties of the aggregates are unrelated to those of the constituents, and associate these two inconsistent ideas every time a substance is discussed, shall we not, as a result of persistent suggestion, finally hypnotize the pupil into a frame of mind in which logical consistency is no longer a test of credibility, and shall we not thus undo in a few weeks the results of the slowly wrought training, in which the instructors in other sciences and in mathematics have prided themselves? Will it not, after all, indicate a saner point of view if we say as little as possible about the relation of the atomic hypothesis to those things which it was not primarily devised to explain?

A science may be compared to a large territory. The study of the science means the exploration of the territory; the examinations of its mountains and minerals, of its rivers and lakes, of its trees and diversified vegetation, and of its numerous animal inhabitants. A lifetime is required for any sort of full knowledge of the territory. But for the purpose of giving some introduction to its chief features, say to the student who can spend only a few hours a week for a year upon the task, the best way is to take him to some point from which those chief features may be seen. From this viewpoint we describe to him the objects he has not himself time to visit and by the help of short

excursions give him the opportunity of handling a few of the more accessible things, and so enable him to realize to some extent the nature of the others. Now, obviously, to give a true conception of the whole, the viewpoint must be chosen with some care, otherwise a hay-stack may cut off half of the horizon, or an ant-hill on a plain may seem to overtop the Rockies. Some of us, feeling confident that our viewpoint has been chosen with exceptional success, set up a camera, take a snap-shot of the subject, and circulate the prints under the name of So and So's *Complete Chemistry*. And if the photographer has been less judicious in his choice of a viewpoint than we could have wished, the result may be very confusing to our pupils. We teachers, who have seen the science from other sides, may have considerable difficulty in explaining the picture so as to restore to their true proportions objects near to and far from the viewpoint. How unfortunate, for example, it is that the camera is so often planted right behind a molecule! What a heavy task this lays upon the teacher who has to reduce the all too obvious atoms to their true place and proportions! Naturally the more distant objects, the trees and mountains, are assumed to be stuffed with atoms, such as abound in the foreground. Naturally, also, the excursions from which we had hoped so much turn out a disappointment; atoms prove to be unexpectedly scarce in the laboratory.

It is not suggested that the text-book as a whole is not true; the camera is always truthful and the photograph is perfectly correct as far as its limitations permit. There *are* molecules and atoms in chemistry. But, if our amateur photographers would study the work of professionals before "exhibiting," they would find that hardly one in a thousand of the detail photographs taken by chemical investigators show any atoms that are visible to the eye in the finished print. Perhaps, if they made this study they would see that their products should go, if anywhere, to the editor of the "freak photograph" section of one of the magazines, rather than into the hands of beginners in chemistry.

The result of getting atoms into the foreground of the picture is to inject thoughts of them into everything else in view, and therefore to crowd out other and more practical conceptions. Ozone and oxygen, for example, appear in the print, but the most obvious difference between them is, not that one is deep blue and the other pale blue, that one is easily liquified and the

other not, that one rusts silver and the other not, and so forth. No, it appears rather that one has three atoms of oxygen in its molecule and the other only two. And what then does this way of stating the difference amount to? It means simply that ozone is, bulk for bulk, one-half heavier than oxygen, a fact which is, primarily, not chemical, but physical. Again, why is the formmula of hydrogen written H_2? Shall we say that it is because there are two atoms in its molecule? Or shall we say that formulæ represent the composition of equal volumes of gaseous substances, that, when we determine the quantities of hydrogen in equal volumes of hydrogen gas and of hydrogen chloride, we find twice as much of the element hydrogen in the former as in the latter, that, therefore, if we assume the latter substance to contain the unit quantity of hydrogen represented by H, the former contains two unit quantities and must receive the formula H_2? It all depends on our point of view. We may use the literal language of experiment, or we may use the figurative and much more difficultly interpretable language of hypothesis. But there can be little question which mode of expression will convey the actual facts, with the least trouble to the halting mental activity of the beginner. Still again, in what light does the nascent state present itself? An element is "nascent" when "it is just being liberated," we say, and, before we can stop ourselves, the atoms in the foreground have cast their shadow on the subject and we add, " the 'atomic state' and the 'nascent state' are therefore synonymous expressions." But, apart from the possibly over-emphasized circumstance that it has just been produced, what is peculiar about hydrogen which is being generated from zinc and hydrochloric acid? It is free hydrogen, still adhering to the surface of the zinc. Is not its activity then due to the contact action of the zinc as a catalytic agent? Why is the nascent hydrogen from tin and hydrochloric acid different in its activity, and why does that from aluminum and caustic soda represent still another degree of activity? As far as age is concerned they are all equally recent in their formation. But the metals in contact with the hydrogen are different and their catalytic effects may therefore well differ. Why use an imagined explanation when a real and plausible one is available? A different, but equally satisfactory set of considerations can be adduced to show that "nascent" oxygen too is simply another

hallucination, born of an unhealthy and too engrossing contemplation of atoms.

But we must leave this diverting subject and look for another of those parts of the science whose treatment is significant of the point of view. The definitions and statements of principles will be found to afford an admirable supply of "test samples." The same chemist who states the law of multiple proportions, as nearly all do, in the literal concrete way with which we are familiar, is likely to become figurative even when he deals with so practical a subject as "physical change." He may say that it is a change in which the relations of the molecules have been altered, while those of the atoms are not affected. Yet he might easily say something that would be of more assistance to a beginner who was watching a vessel of boiling water. Fortunately "physical" and "chemical change" often are clothed in everyday language, but there is at least one conception that is almost never defined in literal terms, namely, valence. For example, "the valence of an element is that property which determines the number of atoms of another element which it can hold in combination," or, "the valence of an atom is its power for holding other atoms in combination, that of hydrogen being the standard." We note, in passing, that one defect of the atomic method of defining valence seems to be that a really exact statement is seldom made. A close reasoner, if such should be found in the class, would discover that, according to the former definition, the valence of hydrogen might be infinity. A chemist reading the second would say that the power of an atom of gold for holding atoms of chlorine in combination is not three times as great as that of an atom of hydrogen, as the definition seems to state, but is in fact very much less. But, even if a theoretical definition free from these defects could be made, as it easily can, would not a literal definition in terms of experimental facts be easier to understand and use? Is not zinc said to be bivalent because an atomic weight of this element combines with two equivalents of chlorine or of oxygen (16 grms.), and displaces two equivalents of hydrogen? Is not the valence of an element, therefore, the number of equivalents of some other element which its atomic weight combines with or displaces? Again, why is zinc bivalent and why does an atomic weight of it displace two atomic weights of hydrogen? Is it not because its atomic weight contains two equivalents of zinc? And is not the valence

of an element, therefore, also, the number of equivalents of the element contained in its atomic weight? The pupils measure equivalents in the laboratory, so they know what an equivalent is, if they know anything.

But let us hasten to take another "test sample." There is no difference in weight between the candle and the consumed oxygen, on the one hand, and the products of the combustion on the other. "We know this because the law of conservation of matter tells us that matter is never created or destroyed." Is our point of view then, that the facts of the science are inferred from the laws? "The periodic system is the expression of a great law, the interpretation of which is one of the achievements of modern chemistry." Do the memoirs of the great chemists show that they busied themselves much with interpreting the statements of fact devised by other chemists? When, by any chance they do so, the abstractor, who seeks to boil down the literature and extract from it the important facts, dismisses the article with the remark "a purely polemical paper," and his point of view is that of the majority.

It would be interesting, if there were time, to take other test samples from the overflowing store. We might ask whether graphic formulæ are really methods of representing valence, or modes of showing the structure of molecules, or attempts to represent chemical behavior graphically. We might inquire whether planting a kodak behind an ion is not as much of a farce as planting it behind a molecule, and whether the older term radical would not, in most cases, convey the meaning in more concrete and tangible shape. We might consider the point of view which brings efflorescence and deliquescence so closely in line that, in spite of their real remoteness, they get into the same page of the finished photograph. But we must try now to sum up our results.

First, and foremost, observation is the only method of securing facts and none can be safely obtained by inference from, or interpretation of laws. Observation in chemistry consists in noting and using experimentally the specific, physical properties of substances.

Secondly, plain, literal, experimental terms are the best for stating facts. Facts are understood to include laws and also definitions of conceptions based on facts. The final statements are to be in terms of physical realities exclusively.

Thirdly, hypotheses are to be used only for explaining and relating facts. They furnish the intermediate steps needed to help us in following the relations of facts, but when we have grasped the relation the steps are no longer required. They are like the scaffolding by which the inaccessible parts of a building are reached during construction. But it would be a poor architect who managed to cause parts of the actual structure to rest here and there on portions of the scaffolding, so that the latter could not all be removed at last. Is there in chemistry any fact, law, or conception based on facts which cannot be cleared of hypothesis and stated finally in experimental terms?

Do not these three propositions constitute a creed for the teacher of chemistry, or indeed of any other science? And by a creed is meant, not a formula which is repeated daily without conscious thought, but a touchstone in constant use for determining the genuineness of every utterance. May not the habitual employment of these propositions lead to the acquisition of a point of view whose outward manifestations will be sound, sane, and above all intelligible speech, a point of view fitted to guide one in the presentation of the elements of the science, with a reduction in scale suited to the purpose, but without needless and misleading distortion?

For the fourth time in the history of the United States the production of coal in 1905 reached a total of over 300,000,000 short tons, showing an actual output of 392,919,341 tons of 2,000 pounds, valued at $476,756,963. Of this total the output of anthracite coal amounted to 69,339,152 long tons (equivalent to 77,659,850 short tons), which, as compared with the production of 65,318,490 long tons in 1904, was an increase of 4,020,662 long tons, or 6 per cent. The value of the anthracite coal at the mines in 1905 was $141,879,000, as against $138,974,020 in 1904.

The output of bituminous coal (which includes semianthracite and all semibituminous and lignite coals), amounted in 1905 to 315,259,491 short tons, valued at $334,877,963, as compared with 278,659,689 short tons, valued at $305,397,001, in 1904. The increase in the production of bituminous coal in 1905 over 1904 was therefore 36,599,802 short tons in quantity and $29,480,962 in value.

PROBLEM DEPARTMENT.

IRA M. DELONG,

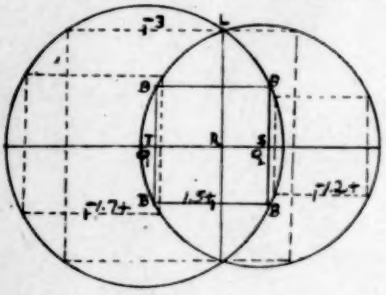
University of Colorado, Boulder, Colo.

Readers of the Magazine are invited to send solutions of the problems in this department and also to propose problems in which they are interested. Solutions and problems will be duly credited to the author. Address all communications to Ira M. DeLong, Boulder, Colo.

24. *Proposed by R. C. Shellenbarger, Yankton, S. D.*

Inscribe a square within the part common to two intersecting circles.

Discussion by E. L. Brown, M.A., Denver, Colo.



In the circles whose centers are O, and O_2, let $O_2R = n$, $O_1R = m$, $LR = c$, $BS = x$, $TR = y$. Then $c^2 + m^2 = x^2 + (m + 2x - y)^2$ .....(1)

and $c^2 + n^2 = x^2 + (n + y)^2$ .....(2)

From (1) and (2), by subtraction, we get

$$y = \frac{2x^2 + 2mx}{2x + m + n} \quad \ldots\ldots\ldots\ldots (3)$$

From (2) and (3) we have

$$8x^4 + 12(m+n)x^3 + (5m^2 + 5n^2 + 14mn - 4c^2)x^2 + (m+n)(4mn - 4c^2)x - c^2(m+n)^2 = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots (4).$$

As long as the circles intersect, C is real, making the absolute term negative; hence, in this case the quartic has at least two real roots, one positive and one negative.

Now every algebraic solution of the general quartic calls for the solution of an auxiliary equation of the third degree. When the roots of the quartic are all real, the roots of the reducing cubic are all real. When the roots of the reducing cubic are real, the solution fails, because we unavoidably encounter the determination of the cube root of a complex number, for which no general method is known.

Letting $n = 1$, $m = 2$, $c = 3$, equation (4) becomes

$$8x^4 + 36x^3 + 17x^2 - 84x - 81 = 0 \quad \ldots\ldots (5)$$

This equation has four real roots: -3, $1.7+$, $-1.2+$, $+1.5+$.

Since this equation has four real roots, we see that the proposed problem is included in the following: Having given two circles, construct a square whose vertices shall lie on these circles, such that one pair of vertices shall lie on one circle, and the other pair on the remaining circle.

For certain values of m, n, c, there will be four such squares, and the roots of equation (4) denote lengths of sides of these squares. When all four roots are real, apparently one root will be positive and the other three negative, the positive one denoting the side of the square in the part common to the two circles.

Since one root of equation (5) is -3, the other three are roots of $8x^3 + 12x^2 - 19x\ 17 = 0$..... (6)

Clearly the value of x which denotes the length of the side of the square in the segment common to the two circles, must be a root of equation (6).

Now this is an irreducible cubic, whose coefficients are rational numbers, and whose three roots are real. Hence, this equation cannot be solved by *real* radicals.

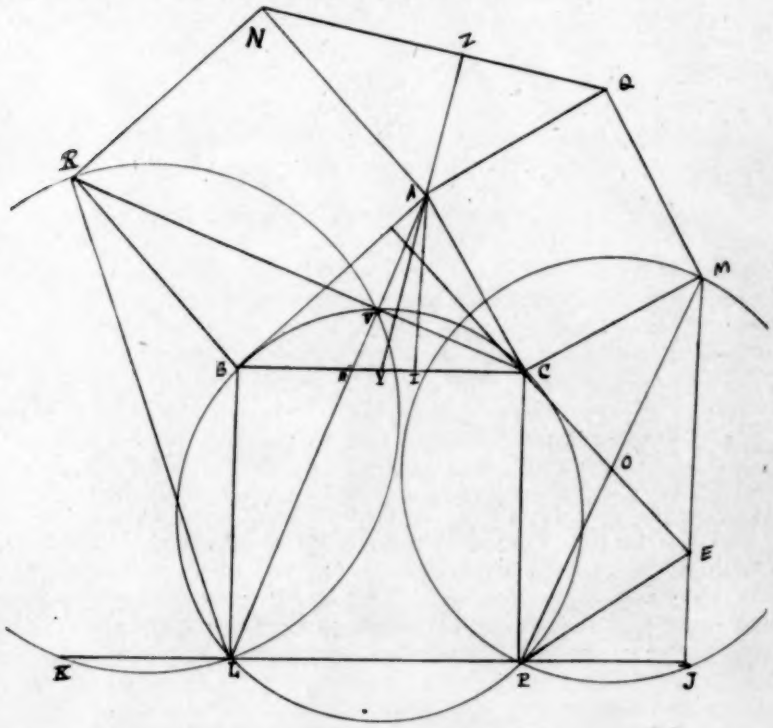
The necessary and sufficient condition that an analytic expression can be constructed with straight edge and compasses is that it can be derived from known quantities by a finite number of rational operations and square roots.

Since the roots of this cubic cannot be determined by rational operations and square roots, the value of x cannot be constructed by straight edge and compasses; that is, the problem cannot, in general, be solved by elementary geometry.

35. *Proposed by J. L. Brown, San Marcos, Tex.*

ABC is a triangle, right-angled at C; M, N, R squares on the sides AC, CB, BA; PS and TK are lines joining adjacent vertices of N, R and M, R. Prove that the common chord of the two circles on PS and TK as diameters passes through C and the mid-point of KS.

Extension by J. J. Browne, Golden, Colo.



Two solutions for this problem were given in the December number. The proposition is true for any triangle; that is to say, squares being described on the sides of *any* triangle ABC and circles being described on RL and PM as diameters, the middle point of LP is on the radical axis of these two circles and A is the radical center of these two and the circle round the square BP.

Comparing the congruent triangles RBC and ABL, the angles at C and L are equal, and the angle BHL = VHC .·. LVC is right .·. the circle on RL as diameter and the circle round the square BP both pass through V .·. A is on their radical axis: similarly A is on the radical axis of the circles BLP and MPJ .·. A is the radical center of the three circles.

Again take O middle point of PM, draw COE making OE =CO then MCPE is a parallelogram, PE = CM = CA, ME is perpendicular to LP .·. their intersection J is on the circle, and AI being drawn perpendicular to BC we have AI and AC respectively perpendicular to PJ and PE .·. the angle CAI = EPJ and AC being = PE we have PJ = AI; similarly KL = AI .:. KL = PJ and .:. the middle point of LP is on the radical axis of circles KLR and PJM.

41. *Proposed by H. C. Whitaker, Ph.D., Philadelphia, Pa.*

The sides of a rectangular room are 39 feet and 31 feet respectively. A rectangular strip of carpet of area 225 square feet is laid diagonally across the room in such a manner that each corner of the carpet touches one side of the room. Find the two dimensions of the carpet.

Solution by F. C. Asbury, Toronto, Canada.

If x and y are the sides of the smaller right triangle cut off by the strip from the sides 39, 31 respectively, we have, by similar triangles,

$$\frac{x}{y} = \frac{31 - y}{39 - x} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The sum of the areas of the triangles is $xy + (39 - x)\ (31 - y)$, hence,

$$xy + (39 - x)\ (31 - y) + 225 = 39 \times 31 \ldots\ldots\ (2)$$

The solution of these equations gives $x = 3$, $y = 4$; the width of the carpet is therefore 5 and the length 45.

42. *Proposed by Ralph E. Root, Sc.B., Forest City, Iowa.*

If in a given circle a triangle ABC be inscribed, the bisectors of whose angles meet at P, show that the perpendicular bisectors of PA, PB, and PC intersect by pairs in the circumference of the given circle.

Solution by Wm. B. Borgers, A.B., Grand Rapids, Mich.

Let BP cut the circumference at F, AP at E, CP at D. Draw FD, FE, FA. Denote the intersection of FD and AP by G. Since arc AF = FC, AD = DB, BE = EC, angle DGA = DGE. Also angle FPA = FAP. Therefore FD is the perpendicular bisector of AP. Similarly FE is the perpendicular bisector of PC, and DE is the perpendicular bisector of BP.

43. *Proposed by H. C. Whitaker, Ph.D., Philadelphia, Pa.*

A heavy sphere of radius r is placed in a glass of water in the shape of a cone, radius R and height h. How much water runs over?

Solution by I. L. Winckler, Cleveland, O.

Let ABC be section of cone through the axis CE; O = center of sphere of which HDFG is section by plane through axis of cone. Let section of sphere touch AC at D, cut axis of cone at F and diameter of base of cone, AB, at G, and axis of cone produced if necessary cut circle again at H.

Then from similar triangles AEC and ODC we get

$$\frac{r}{R} = \frac{OC}{\sqrt{R^2+h^2}} \quad \therefore OC = \frac{r}{R}\sqrt{R^2+h^2}$$

$$FC = OC - r = \frac{r}{R}\left(\sqrt{R^2+h^2} - R\right)$$

$$EF = h - FC = \frac{Rh - r\left(\sqrt{R^2+h^2} - R\right)}{R}$$

Now the volume of a spherical segment of altitude EF is

$\frac{\pi}{3}\overline{EF}^2(3r - EF)$, therefore the volume of the submerged part is

$$V = \frac{\pi}{3}\overline{EF}^2(3r - EF) = \frac{\pi}{3R^2}\left\{3Rr\left[Rh - r\left(\sqrt{R^2+h^2} - R\right)\right]^2 - \left[Rh - r\left(\sqrt{R^2+h^2} - R\right)\right]^3\right\}$$

If the sphere is wholly submerged, EF=2r, and $V = \frac{4}{3}\pi r^3$ as it should. This solution assumes that the sphere sinks in the water.

CREDIT FOR SOLUTIONS RECEIVED.

24. E. L. Brown.
29. Eugene R. Smith.
35. J. J. Browne.
36. Mary Augusta Clark, Louis Lindsey, F. R. Keck, Eugene R. Smith.
37. John W. Scoville, Wm. B. Campbell, F. R. Keck, Eugene R. Smith.
38. Eugene R. Smith.
39. F. R. Keck, Eugene R. Smith.
41. F. C. Asbury, I. L. Winckler, T. M. Blakslee, Wm. B. Borgers, J. Alexander Clarke, H. C. Whitaker.
42. T. M. Blakslee, Wm. B. Borgers, F. R. Keck, I. L. Winckler, John P. Clark, Ralph E. Root.
43. I. L. Winckler, T. M. Blakslee, H. C. Whitaker.

Total number of solutions, 29.

PROBLEMS FOR SOLUTION.

ALGEBRA.

Proposed by I. L. Winckler, Cleveland, O.

A and B run around a course, starting from the same point, in opposite directions. A reaches the starting point 4 minutes, and B 9 minutes, after they have met on the road. If they continue to run at the same rates, in how many minutes will they meet at the starting point? (From Wells' Algebra.)

GEOMETRY.

Proposed by Byron E. Toan, Boulder, Montana.

In a circle, radius R, given an arc of 45 degrees. To find the radius of a circle passing through the extremities of the given arc and having the area common to the two circles equal to 2/5 of the area of the required circle.

Proposed by Mary E. Barkley, Sacramento, Cal.

Find the locus of all the points, the sum of the squares of the distances of any one of which from *three* given points is equivalent to a given square.

TRIGONOMETRY.

Proposed by T. M. Blakslee, Ph.D., Ames, Iowa.

If $X + Y + Z = 180°$, $\tan X + \tan Y + \tan Z = \tan X \tan Y \tan Z$.

Use this to find the radius of a circle inscribed in a triangle in terms of the sides.

APPLIED MATHEMATICS.

Proposed by Chas. H. Smith, M.E., Chicago, Ill.

A can trust is to be formed by the different companies now making the separate parts, pooling their interests; the capital is to be one million dollars. The trust is to pay the different firms by issuing 60 notes payable one each month for 60 months. The face value of each of the notes, including interest at six per cent is to be the same. What is the face value?

The production of platinum from domestic ores in 1905 was 318 ounces, valued at $5,320, as compared with 200 ounces, valued at $4,160, in 1904; with 110 ounces, valued at $2,080, in 1903; with 94 ounces, valued at $1,814, in 1902; with 1,408 ounces, valued at $27,526, in 1901; and with 400 ounces, valued at $2,500, in 1900. In December, 1904, the price of ingot platinum at New York advanced from $18.50 to $19.50 an ounce; in April, 1905, it was $20.50; in February, 1906, it advanced to $25, and in September, 1906, it was $34 an ounce.

The production of copper increased from 812,537,267 pounds, valued at $105,629,845, in 1904, to 901,907,843 pounds, valued at $139,795,716 in 1905, an increase of 89,370,576 pounds in quantity and of $34,165,871 in value.—*U. S. Geol. Survey Bulletin 260.*

EXPOSITION, EXPERIMENT AND DISCUSSION IN THE TEACHING OF ELEMENTARY PHYSICS.*

By Professor A. Wilmer Duff,

Worcester (Mass.) Polytechnic Institute.

The somewhat imposing title of my address is the outcome of two suggestions made by the president of the Association in asking me to take part in your discussions. The first suggestion was that I should give especial attention to the question whether lectures should have any place in the teaching of elementary physics, and the second was that I should, if possible, introduce some appropriate experiments in illustration of my views. In endeavoring to meet both of these suggestions I was led to adopt as my subject the relations of the factors of instruction, which I have called exposition, experiment and discussion. If this program should appear to you rather over-ambitious and perhaps somewhat pedantic, your president and I must bear the blame in somewhat equal proportions.

One point I must make clear at the outset. While I shall emphasize a certain method of teaching physics, because after many years of varied trials I have found it to be the best, I must not be understood as implying that it is the only satisfactory way for all teachers. Many teachers have chosen or been compelled by circumstances to adopt some other method, and zeal and wisdom have enabled them to attain great success with it. My only excuse for presenting my views is that the experience of any one teacher, clearly presented, should contain some suggestions of value to other teachers, provided it be experience, and not mere theorizing, that is presented. The teaching of elementary physics presents the same problems whether it be in a school or in a college. The subject matter may differ slightly in extent, but the best method in the school is, I believe, also the best method in the college.

In many points, I take it, we are all agreed, and it may not be amiss if I state some of them. Without some enthusiasm for learning, some positive desire to know, little worth the name of learning can be acquired; and without some positive enthusiasm for imparting knowledge no teacher can expect to arouse and sustain the interest of his students. The amount a student learns bears very little relation to the amount of time he expends on his work if it be performed merely from a sense of necessity; it is more nearly proportional to the active personal initiative the student can be inspired to put into his work. Dull grinding is not study and dull pounding is not teaching. The first aim of teaching must be to inspire enthusiasm. Nearly all students can be stimulated to some degree of enthusiastic endeavor. The necessary conditions are, I believe, the stimulus of an enthusiastic teacher and the stimulus to thought that comes from doing something that promotes thinking. In saying this I do not mean to imply that drudgery, the work that calls for a positive effort of the will, can be avoided

* Address before Eastern Association of Physics Teachers at Simmons College, Boston, on March 24, 1906.

or should be avoided, but the necessary impulse should come from the vision of the future reward of the effort and not from the mere necessity of doing.

While for clearness I have taken exposition, experiment and discussion as the topics of my talk, you may, if you will interpret the words as I shall, replace them by lecture, laboratory and recitation. Some teachers, probably very few, now rely on one of the three only; in the school it is mostly the recitation and in the college the lecture. The majority employ two of the three, in the school the recitation and the laboratory, and in the college the lecture and the recitation, while only a minority in either employ all three in close combination. Yet it is my belief that neither in college nor school can the best result be obtained without the simultaneous use of lecture, laboratory and recitation in the closest possible combination.

No doubt I shall fail to carry all of you with me when I say that a lecture or exposition is an important part of the best physics teaching. Possibly those who dissent are thinking of the vague popular declamation that formerly passed for a lecture on a scientific topic. That is by no means what I mean by a lecture, considered as an exposition of some important principle to a class of beginners. Nor do I mean the lecture of our fathers' time, which was the beginning and the end of teaching. Many of us remember some such lecturer and the admiration he inspired. Of him you may hear old students say, "Professor Blank was a wonder. What he didn't know about (say physics) wasn't worth knowing," and those who say so were frequently those who learned least. The truth was, the finished and polished lecturer, Professor Blank, was often the only one in his classroom who was learning, the only one who was perpetually seeking, examining, weighing, comparing; the rest were only admiring. If they had also been searchers, while they might not have left with the same kind of admiration for the instructor, they might have conceived another and more fruitful admiration of him as a fellow student and very fallible searcher after truth. The fascinating lecturer is sometimes a pitfall to his students. He asserts, they accept; he puts the whole thing in a nutshell, they only need to put it down in their notebooks and there they have the whole unalterable creed necessary for the solution at the examination. A small number, perhaps, catch inspiration, the rest go mentally to sleep when their admiration has been sated.

Now the lecture or exposition I have in mind is something different. I must repeat that I am here speaking of the teaching of elementary physics. The chief aim of the lecture should be to stimulate the student to do and try for himself. Starting with the experiences of everyday life, it should group those about the important principle which is to be the subject of the next laboratory exercise, thus engaging at the outset the attention of the class. The meaning and bearing of the principle should be expounded with all the clearness and deliberation possible, continuous appeal being made to past experience. It should proceed at such a rate that at least two thirds of the class have no difficulty in following it without previous preparation from a text-book. Above all it should not be packed with mere facts, figures and formulæ which can

be best acquired from a text-book. Simple illustrative experiments that involve no elaborate, confusing apparatus may be used to lend interest and emphasis to leading points. No more rote repetition of a text-book will do. The lecturer should feel the presence and attitude of his hearers, note how well they are following and where his explanations need repetition and amplification.

A simple, familiar style of delivery is no doubt best, and considerable variety of delivery will prevent undue strain on the attention of the class.

Many, I am aware, regard such a lecture or exposition as a superfluous and rather useless exercise, especially when delivered to a class that has not prepared the part of the subject of which the lecture treats. They reason that it must be more or less useless since the ordinary listener cannot put it down in his notes and must after all depend on a text-book. Yet I think those who reason thus overlook some important facts. In the first place a clear exposition by a lecturer who is vitally interested in his subject and in his audience is a source of stimulus and inspiration that no book can equal. The living voice and presence of the speaker command an interest that dead type cannot supply. Enthusiasm is a matter of contagion, not of long distance transmission, no matter how high the pressure may be at the other end of the line, and in the next place the author of the book may know his subject much better than the speaker, but the latter knows his class and their immediate needs and difficulties infinitely better. He can, if he adopts the proper pace, induce his hearers to follow him in thinking out clearly and logically the steps by which a principle is arrived at, thus helping them to avoid pitfalls that beset the path of the unwary reader and gain clear first impressions, and in the third place such a teacher will gain the confidence of his class. Confidence in one's guide is a prime requisite in an excursion into the unknown and the teacher who is felt to be the mere examiner of his class on ideas which are repeated from a text-book, suffers from a serious disadvantage.

Such an exposition requires careful preparation, but it is repaid by the interest it stimulates. Moreover, it has a most valuable reflex action on the teacher's attitude toward his own subject. It calls for continual reading and thought regarding the foundations of his statements and this freshness of interest is felt as a continual stimulus by the class. No teacher can teach with freshness and interest if he is not himself continually learning. He will, of course, exercise caution and self-restraint in the amount of his increasing knowledge which he places before his class, but his growing command of his subject will add to the security and pleasure with which he expounds his subject, and the power of readily meeting the questions and difficulties of his more acute and interested students will do much to stimulate that confidence which filters down from the top of the class to the bottom.

Yet important as I consider the lecture, its place is chiefly that of an introduction to the work of the laboratory. I am going to assume that the laboratory exercise on any topic follows with the least possible delay, not more than three or four days, the lecture on the same or

immediately related topics, so that the interest created by the lecture is still fresh. I am going to assume also that the purpose of each laboratory exercise is not the acquisition of skill in measurement or manipulation, or even the acquisition of some fact at first hand, but the gaining of that clear personal insight into some valuable principle which can be gained only by the reflection that is stimulated by personal experience and active trial. Keen observation is important and facts are important and so also is the power of using one's hands deftly and readily, but all these are much less important than the power and habit of correlating facts as principles and distinguishing the essential and fundamental from the accidental and superficial. These are the qualities required by the highest type of citizen as well as by the scientist, engineer, or professional man. If I am right in this assumption it follows that experiments in mere measurements are futile, no matter how stately the columns of figures they prove or how smooth the curves into which the figures plot. Nothing is more disappointing than the attitude of the student who can point with pride to a record book that shows many neat curves and tables of figures, but has no clear grasp of fundamental concepts and principles. I once heard a teacher (at a great distance from Boston) say that he had made his class spend one third of a term on "perfectly accurate" measurements with a micrometer caliper. He meant it as a boast, but I thought it rather a confession.

But here I must not be misunderstood. Very few laboratory exercises are worth performing that do not call for observation and measurement of the highest accuracy in the student's power. Physics is a science, that is, a body of related principles founded on carefully ascertained facts. Life would be too short for any one student to perform all the experiments and make all the measurements that would completely establish even one important principle. But every laboratory exercise should lead the mind to reflect on some principle or concept much wider than the mere results of the exercise. Not experience but the fruits of experience (to reverse Walter Pater) should be the aim, and among the fruits of laboratory experience should be a clearer grasp of the concepts and principles of physics than any lecture or text-book can convey. A laboratory exercise should be interesting, pointed (that is, pointed at some principle or more than one) and should call for the most careful measurements. There is another quality that it should have. Nothing affords a student more satisfaction than some test of his work, and this a good laboratory will furnish. The result should be ascertained in more than one way. The most valuable form the check can take will be the agreement of an experimental result and a result deduced from theory or principle. The degree of accordance will set the mind to account for any difference and the attempt to account for small discrepancies will lead the student to a clearer recognition of the meaning of the work and the steps and principles involved than anything else can. One other thing should guide us in the design of exercises. Some principles of much abstract scientific importance may have very little relation to the future activities to which the class as a whole look forward, and it should not be difficult to choose or design

a sufficient number of exercises that combine the qualities of scientific importance and practical interest. I believe we sometimes err as teachers of physics from an unconscious bias in favor of making our students physicists or teachers of physics, while the great majority of them intend to follow some humbler but more lucrative calling.

It is no disadvantage in an exercise that it should suggest questions that cannot be answered at the stage of the subject which the student has reached, in fact it is an advantage, provided the unexplained element does not mar the clearness of the principle which the exercise is intended to elucidate. Something that points to the future arouses interest and expectation and helps to prevent the impression that science consists of separate, disjointed facts or unrelated principles. It is also a most valuable feature in an exercise that it should imply references to previous exercises, thus serving for review and adding continuity.

I think that many of you will agree with me that much still remains to be done in the way of devising instructive exercises for the laboratory both in the school and in the college. In both we have too many exercises which have little real value but hold their place because of the ease and accuracy with which they can be performed, while many more important topics are not represented in the laboratory program, because they do not lend themselves so readily to easy and accurate measurements. This I think is especially true of elementary mechanics, the fundamental and most important part of the subject. While we have an abundance of statical experiments, exercises in acceleration, centrifugal force, momentum, kinetic energy, potential energy, work, etc., are almost lacking, yet the conservation of energy is the greatest of physical principles and a thorough grasp of it would be worth all the rest of mechanics.

In speaking of the work of the laboratory I have been assuming that all the students in a class or section perform an exercise simultaneously. This is, of course, not at present the case in many laboratories, but it is, I believe, the ideal method, permitting the instructor to give hints and directions with a readiness not otherwise possible. The chief difficulty is one of expense, but much of the apparatus now in use is, I think, unnecessarily elaborate and expensive. Let us, however, suppose that four outfits for each exercise are available. If two students work together (an evil, but perhaps an unavoidable one) two exercises may run simultaneously and so a class of sixteen may be employed on not more than two exercises at once. In those circumstances most of my remarks still hold good.

Let us turn now to the third topic in my subject—the discussion, or, call it recitation if you will, provided you understand the same thing by it as I do. A valuable laboratory exercise will suggest points to a student which he may not be able to think out clearly. Such difficulties may, of course, be met by the instructor; but it will be vastly more profitable to the class if the other members of the class can be induced to do the necessary thinking. Many students will perform parts of the exercise in a more or less mechanical way without realizing the full

meaning and purpose of the work. Some will fail to look beyond the particular facts to the general principle involved, and some will fail to get satisfactory results without being able to account for their failure. A full and free discussion of the experiment is of the greatest value and awakens the liveliest interest. It completes the development and fixes the picture; without it both lecture and laboratory may result in a blurred image which will quickly fade from the mind. The discussion may start with questions by the teacher intended to bring out into strong relief the important points of the experiment. Questions by the teacher will be succeeded by and intermingled with questions by the class, the answers to which should if possible also come from the class. Questions on related parts of the text-book, numerical problems of a related nature, application of the principle of the experiment in nature or in industries, questions in review of past work and others that point to future exercises will make the study a thing of life and interest very different from the dull rote repetition of text-book statement, into which the mere recitation is apt to degenerate. More than one hour may be devoted to the discussion of an exercise, and on the other hand, more than one laboratory exercise may be taken up in a single discussion, as the experience and judgment of the instructor may dictate.

No doubt you have at your meetings devoted no small amount of attention to the merits and demerits of text-books, and I hesitate to approach such a dangerous topic. Yet my sketch would be incomplete without some reference to it. The course I have outlined aims at weaving exposition, experiment, and discussion together in the closest unity, and the text-book should, I believe, show a similar unity. Laboratory exercises should appear in their proper setting in the general text-book and not in a separate manual. The statements of the descriptive text should be characterized by brevity and clearness, and the work of deliberate exposition, with profuse illustration, should be left to the oral exposition. Undue prolixity is as great an evil as undue brevity, for the essential point of a paragraph is often lost, if the paragraph is packed too full with the unessential, while a compact statement, provided it be clear, can be read until the full sense is extracted. Too much water weakens the digestive juices, and a statement of principles cannot be predigested by dilution. Elaborate details in the laboratory instructions leave nothing to exercise the judgment and imagination of the worker and reduce him to the level of an unintelligent automaton. The repetition, in the instruction, of formulæ necessary for calculation is undesirable; if forgotten, they should be sought for in the general text. Questions for discussion and appropriate problems should follow the account of the exercise. Tabular blanks for entering results of measurement are usually undesirable. They often tempt the student to work blindly and confine his attention to finding figures to fit the formulæ and fill the blanks. The instructor may supply such as he thinks necessary in the lecture which precedes the exercise or on the laboratory blackboard.

In closing let me admit that in what I have stated, at perhaps undue length, I have not said or attempted to say anything essentially new. I have been stating my experience in the hope that it may agree with

your experience and confirm you in your conclusions. Teaching is not a matter of fixed rules or unalterable methods, whatever theorists may assert; it is a matter of common sense, intuition, and experience. I thank you for the invitation to be present and for the attention you have so kindly given me.

In illustration of his views regarding laboratory exercises the speaker explained and illustrated three experiments which have, to a considerable extent, the necessary qualities of instructiveness and the use of simple instrumental means. One of these (invented for the occasion) was a method of studying uniform acceleration. The apparatus consisted of a steel ball and a plank four feet in length in which was a longitudinal groove of circular section. The groove was painted black and polished smooth. Lycopodium powder was dusted on the groove. When the ball was rolled down the groove it had a uniformly accelerated longitudinal motion and a vibratory motion, like a pendulum, across the groove, and the trace of its motion was left very sharply defined when the powder was blown off. The distance traversed by the ball during each vibration was measured along a white thread stretched along the groove and the proportionality of the distance to the square of the time was more accurately verified than in any more complex arrangement for the same purpose. By varying the inclination of the plank the cosine law could be tested. The ball could also be propelled up the groove and uniform retardation studied. When a smaller ball was used, the loops of the curve were longer, for, while the acceleration remained the same, the vibrations of the smaller ball were slower since it constituted a pendulum of greater length, thus illustrating the law of the pendulum. The best way of finding the actual time of vibration of the ball is to arrange a separate pendulum to keep time with the ball and then time the separate pendulum. The time of vibration of the ball depends on the amplitude of the vibration, when that is large, as is also the case with the ordinary pendulum. To completely remove the trace of the ball from the groove, the latter must be washed. If it is merely rubbed with a dry cloth the trace will reappear when the powder is next dusted on the groove. The trace made on the powder is very interesting as it consists of a ridge of powder between cleared spaces (compare the action of an automobile or bicycle tire on a dusty road). A very striking lecture experiment is to use fine sulphur powder and develop the trace by raising the plank and striking it on end on the table. (As pointing to more advanced work it may be noted that the actual acceleration of a ball rolling down an incline is 5-7 g cos i, and if the time of vibration of the ball is to be calculated from the radius r and the radius of the groove R by the formula for the pendulum, the length of the pendulum must be taken as R-r and the value of g replaced by 5-7 g.) The coefficient of kinetic friction may be found by placing the plank on an incline board and finding the acceleration of the ball at the groove, first when the groove is stationary, and then when it is allowed to slide. For this purpose a much shorter grooved plank may be used.

The other two exercises were on centrifugal force and on the connection between kinetic energy, potential energy, and work, but they need not be described as they have already appeared in print.

N. H. B.

UNIVERSITY OF NORTH DAKOTA, GRAND FORKS, N. D.

TO THE EDITOR,

Dear Sir:

Circular IV on "The New Movement Among Physics Teachers," published in the December number of this journal, contains the following:

"The course outlined in the following syllabus is supposed to be a one-year course in the third or fourth year of the secondary school. The course should be preceded in the first or second year by a simpler and more qualitative course in general physical science. The encouragement of the establishment of such courses is one of the aims of this outline."

Just how much of this proposed course in "general physical science" shall be physics is not stated in the circular, but presumably that subject will furnish a considerable portion of the work. I regret that such a preliminary course is to be encouraged, and venture to submit to the readers of this journal some objections which I think worthy of consideration. In order to simplify the discussion the argument is made against a preliminary course in physics in the secondary school, but, inasmuch as the objections are not based upon a course of any definite length, it is thought they will apply to the course that it is proposed to encourage. In other words, the arguments here advanced should be considered if any preliminary work in physics is contemplated.

I presume that the enthusiasm of the teachers, the supposed need of more physics in the secondary school, and the need of previous preparation for the year's work as now given are some of the factors which are responsible for this desire on the part of the teachers of physics. A confession of the need of previous preparation acknowledges at once that the desire for this preliminary course is due in a large measure to a weakness in the work as now given. Suppose that the present year's work were taught in a highly satisfactory manner, would anyone be proposing a previous course? If the year's work were successfully taught, there would be no desire for an earlier and more elementary course, but rather for a subsequent and more advanced course. There is no complaint as to the ability of the teachers or their devotion to their work, but they cannot be expected to teach the subject successfully when handicapped by a course which is not suitable. It is my point, therefore, that we (according to the proposal) are not attempting to remove the source of the difficulty, but rather attempting to overshadow it by a remedy which does not reach the cause. It may easily be true that those who have tried the scheme are pleased with the results. I submit, however, that the relief they find is only temporary, for if the cause of the trouble is not removed it may become aggravated and in a few years cause as much distress as before the application of the supposed remedy. In other words, the introduction of the preliminary course will aid in a tendency which we should strive vigorously against, i. e., making the secondary school work in physics too technical and consequently too difficult.

Every enthusiastic teacher has a strong inclination to teach all he knows, even at the expense of making the entire work less attractive. Consequently, the question of the character of the secondary school course will not be forever solved by the work of this commission. Their syllabus and their suggestions will be of great benefit, but, after the present agitation ceases, the physics course will again gradually grow more difficult and less interesting until another similar but greater reaction takes place. I therefore look upon this proposal for a preliminary course as a dangerous proposition, for it is an aid to the establishment of a more difficult year's course.

It is not hard to understand that this preliminary course might be more interesting than the year's work now is, but that does not signify that the enthusiasm and spirit present at the close of the subsequent year's work will be better than now. The necessary repetition involved in the two courses is bound to detract. Those who have found that such a preliminary course does apparently aid in the attractiveness of the subsequent work will assert that they know whereof they speak by experience. They should remember, however, that a course which is too difficult without previous training is bound to be made more attractive when bolstered by such training.

The college may be regarded as the place where the scientist is created, but my conviction is that the future of the scientific work in this country rests very largely in the hands of the secondary school teachers. At present, the student in the secondary school, who has really a scientific trend, has had ground into him so many formulas and technicalities that he fails to see the real future in the life of a scientist. The scientific field being closed to his vision, his natural bent finds expression in the selection of engineering as his profession. When he has once entered upon his studies, only opportunities which are exceedingly striking will divert his attention. The future men of science therefore depend for their inspiration largely upon their secondary school instructors. The inspirational character of the work is of very great importance not only to the future man of science but also to the scholar whose training in physics must be confined to the secondary school. Technicalities are not an aid to inspiration. Let us have a year's course which will need no preliminary work, one that can be successfully conducted, one that will be at once a source of information, training and inspiration. I believe this syllabus will furnish the basis for such a course, but I find myself emphatically opposed to the suggestion of preliminary work. If educators demand more physics in the secondary school, let that additional work follow the present course.

G. W. STEWART.

The production of manganese ores decreased from 11,995 long tons, valued at $116,722, in 1901, to 7,477 long tons, valued at $60,911, in 1902, and to 2,825 long tons, valued at $25,335, in 1903, and increased to 3,146 long tons, valued at $29,466, in 1904, and to 4,118 long tons, valued at $36,214, in 1905.

MATHEMATICAL NEWS ITEM FROM COLORADO.

The mathematical organization of this state is known as the Colorado Mathematical Society. The meetings are held at Denver. This city will probably be the permanent meeting place, as it is more centrally located than are the other educational centers of the state. The Colorado Scientific Society has given them the use of their rooms in the Chamber of Commerce Building. The membership is constantly growing and all members are workers. The officers are Professor Ira M. DeLong, State University, Boulder, President; and Alwyn C. Smith, State School of Mines, Golden, Secretary-Treasurer.

IOWA STATE TEACHERS ASSOCIATION, DES MOINES, IA. DECEMBER 27, 1906.

MATHEMATICS ROUND TABLE.

Leader, W. J. Rusk, Grinnell; Secretary, Martha A. Beeson, Des Moines. "Methods in Teaching Algebra," Mabel M. Foster, Iowa City High School; "How Long Should the High School Course in Algebra Take?" J. L. Thatcher, Davenport High School; "Mathematics as a Factor in Character Building," Ira S. Condit, Iowa State Normal School; report of the committee appointed at last year's meeting upon "A Practical Course of Study in Mathematics for High Schools," W. A. Crusinberry, West Des Moines High School, Chairman.

The above program was carried out. For lack of time, no discussion of papers was held; for the same reason no action was taken on the report of the committee as noted above.

The following motion was made and carried: That it is the sense of this mathematics round table that it would be better to leave the entire afternoon of the first day of the state meeting open for round table discussions; also that the secretary report this action to the chairman of the next executive committee.

Officers were chosen for next year as follows: Chairman, J. L. Thatcher, Davenport, Ia.; Secretary, Miss Mabel M. Foster, Iowa City, Ia. MARTHA A. BEESON, Secretary.

CHEMISTRY TEACHERS CLUB OF NEW YORK CITY—SIXTEENTH MEETING, OCTOBER 27, 1906.

As has been customary for several years, the club opened the season of 1906-07 with an excursion. The plant visited was the Atlantic White Lead works at the corner of Marshall and Gold Streets, Brooklyn, N. Y., directly on the East River.

Twenty-one members and friends of the club met at 8:45 A. M. on the plaza at the Brooklyn Bridge, and at 9:05 proceeded on foot to the works. Here we were received most hospitably, the entire plant being thrown open for inspection, and both the superintendent, Mr. H. P. Cavarly, and the assistant superintendent, Mr. F. H. Doughty, volunteering to act as guides to the party.

The output of the Atlantic works consists almost exclusively of three products, viz., white lead, linseed oil and lead (and solder) wire, sheet and tubing. As a detailed description of the processes used in making these would be too long for this report, only the briefest statement concerning them can be made.

The white lead is made by the old Dutch process, since this, on the whole, gives the most satisfactory product. From 35 to 40 tons of lead are daily used at these works, the output of white lead being approximately 45 tons.

Ten thousand gallons of linseed oil are daily expressed here, the seed being first heated, since the yield under these conditions is 25 to 30 per cent greater than when cold pressed.

The manufacture of lead sheet, pipe and wire and of solder wire was also seen.

The entire visit was most instructive and enjoyable. Much of the pleasure was due to the attitude of Messrs. Cavarly and Doughty, each of whom gave practically a half day of time to the club. Too much cannot well be said of their unfailing courtesy and kindness, their readiness to answer all questions and the generous way in which they threw the entire plant open for inspection.

Jos. S. Mills, Secretary.

NEW ENGLAND ASSOCIATION OF CHEMISTRY TEACHERS.

The twenty-seventh meeting was held in Boston, November 10, 1906. The following were elected as officers for the year 1906-07: President, James F. Norris, Simmons College, Boston, Mass.; Vice-president, Edward F. Holden, High School, Charlestown, aMss.; Secretary, Augustus Klock, High School, Beverly, Mass.; Treasurer, Miss Lillie C. Smith, High School, Brookline, Mass.; additional members of the Executive Committee: H. P. Talbot, Institute of Technology, Boston, Mass.; Sidney Peterson, High School, Brighton, Mass.; Harold Bisbee, High School, Dorchester, Mass. The following were also elected to membership: Arthur J. Hopkins, Amherst College, Amherst, Mass.; S. Walter Hoyt, High School, Fitchburg, Mass.; Grace E. Purinton, High School, Middletown, Conn.; Leroy F. Swift, High School, Lowell, Mass.; Frank T. Dillingham, Bussey Institute, Jamaica Plain, Mass.

The annual reports of the secretary and the treasurer reviewed the work of the past year and showed the association to be in a flourishing condition. The total membership is now 121.

The chief paper was read by Augustus Klock on "High Explosives." Through the courtesy of Mr. Klock, School Science and Mathematics will soon publish an article by him embodying the essential parts of this paper.

Following the paper on explosives there was a symposium on "The Teaching of Chemical Arithmetic." The subject was presented by Professor James F. Norris and Mr. R. P. Williams, and a brief discussion followed. So much interest was aroused by this subject that it was voted to continue the discussion at the next meeting. Professor Norris emphasized the necessity of teachers having definite knowledge of the ability of each student, the importance of having students grasp the full meaning of a chemical symbol, the advisability of requiring students to visualize the problem, the desirability of testing answers, the value of regular and constant solution of problems, graded problems, correlation of problems and quantitative laboratory work, and individual instruction.

Mr. Williams outlined by diagrams and blocks his method which has given good results for many years.

ASSOCIATION OF MATHEMATICS TEACHERS OF NEW ENGLAND.

The fourth annual meeting of the Association of Mathematics Teachers in New England was held at Simmons College, Boston, Saturday, December 8. In the morning session reports of the committees on Arithmetic and on pattern examination papers in Algebra and Geometry were given.

Professor Levi L. Conant of the Worcester Polytechnic Institute read a very interesting paper on "The Beginnings of Number." Professor Conant stated that the life of the individual is an epitome of the life of the race. The child first perceives number when he distinguishes between one and two. Number as an abstract idea comes late in human development. Probably cardinal numbers were used before ordinals. Illustrations of number concepts of animals and insects were given. Number sense in primitive man was not much higher than in some animals. The speaker discussed the ability of the mind to grasp the meaning of large numbers. He stated the advantages of twelve as a base instead of ten. He showed primitive number systems with bases five, ten, and twenty, proving conclusively that the fingers and toes were used as counters in the beginnings of number.

Discussion of Professor Conant's paper led the association to the metric system and the desirability of using it instead of our present measures. It was agreed that teachers of mathematics should unite in urging the national government to make the change as soon as possible.

Lunch was served to seventy-five members in the dining hall of the college. After lunch an opportunity was given to examine the buildings and equipment of the college.

Officers for 1907 were elected at the beginning of the afternoon session.

Mr. George W. Evans, principal of the Charlestown High School, reported for the committee on geometry. He gave the vote taken by mail on the desirability of adopting the syllabus of Geometry prepared

by the committee. The vote was strongly in favor of the syllabus. The chief objection was due to fear that liberty in teaching might be lessened by a syllabus. This fear was caused by misunderstanding the use which the committee intended should be made of the syllabus. Further action on the syllabus was left in the hands of the council of the association and the council was empowered to print and distribute the syllabus.

Professor Edward V. Huntington of Harvard reported on the June examinations for Harvard in Algebra, advanced Algebra and Trigonometry. He showed solutions of the problems and illustrated the methods used by students. He gave the percentage of success and failure for each question. A great many questions were asked the speaker and he answered them very carefully and completely.

Professor Charles L. Bouton of Harvard explained the paper in Plane Geometry. A lively discussion followed. It was felt by the association that the work of the afternoon was very helpful, since teachers were shown where students failed and why they failed. Votes of thanks were given Professors Huntington and Bouton. A vote of thanks was given to the president of Simmons College for the hospitality of the college.

The officers of the association for 1907 are: President, Charles D. Meserve, Newtonville High School; Vice-president, Harry W. Tyler, Massachusetts Institute of Technology; Secretary, George W. Evans, principal of the Charlestown High School; Treasurer, William B. Carpenter, Boston Mechanic Arts High School; Council, Professor Charles L. Bouton, Harvard University; Professor Thomas W. D. Worthen, Dartmouth College; Henry M. Wright, Boston English High School; Professor Ellen L. Burrell, Wellesley College; Miss Parnell S. Murray, Boston Girls' High School; William T. Campbell, Boston Latin School.

WILLIAM A. FRANCIS.

REPORT OF THE MEETING OF THE ASSOCIATION OF TEACHERS OF MATHEMATICS IN THE MIDDLE STATES AND MARYLAND.

The seventh meeting of the Association of Teachers of Mathematics in the Middle States and Maryland was held at the Central High School, Philadelphia, Saturday, December 1. Both morning and afternoon sessions were well attended.

Dr. Robert Ellis Thompson, president of the Central High School, in his address of welcome among other pertinent suggestions called attention to the overuse or abuse of the blackboard, especially in mathematical teaching. From his own early experience and in later years in watching the experience of others, he has reached the conclusion that a close adherence to written work tends to weaken the student's mental power.

Dr. John Anthony Miller, professor of mathematics and astronomy at Swarthmore College, read a paper on "The Fundamental Theorems

of Elementary Mathematics." Professor Miller stated that a large number of the recently published algebra text-books do not give rigorous proofs of fundamental theorems. A faulty proof is worse than no proof. In most cases, until the student is sufficiently mature to appreciate a rigorous proof, it is better to give him a plain statement of the theorem postponing the proof, rather than attempt to force upon him a line of reasoning which subsequent study will reveal is either fallacious or incomplete. The ordinary beginner's algebra gives too much space to defining number, to distinguishing between signs of quality and operation. While theorems that introduce such difficulties as to be beyond the comprehension of the beginner should be postponed, on the other hand those that admit of clear and rigorous proof should be thoroughly mastered.

Harry English, director of mathematics of the Washington high schools, spoke next on the topic, "The Teacher—His Preparation, Place, and Power." The address was a forceful presentation of the necessity of recognizing and dignifying the profession of the teacher. His problems are as complex and exacting as those which face the lawyer, the physician, or the clergyman. His relation to the home and to the state are as important. His general culture and his special training should be as broad and as thorough as those which are demanded in the other learned professions.

Superintendent Rau, of the Moravian Parochial School, Bethlehem, Pa., treated the topic, "Co-ordination in Mathematics." The speaker contended that in certain sections the laboratory method had been unduly magnified; that teachers of mathematics had more to gain by a closer co-ordination of the recognized divisions of mathematics than by an excess of applications from the natural sciences. Mr. Rau especially advocated a closer union of geometry and trigonometry. He feels that the course in geometry should be much abridged by treating those elementary theorems of which all students have correct ideas as axiomatic, and proceeding to demonstrate propositions not so familiar. Thus he would classify most of the propositions concerning parallels and perpendiculars as fundamental propositions requiring no proof. He would use the time thus gained in more advanced work in geometry and trigonometry.

Dr. Alice M. McKelden of the Girls' High School, Philadelphia, led a general discussion with her paper, "The Problems that Arise in the Teaching of Elementary Algebra." Miss McKelden believes that teachers should carefully instill accurate definitions with plenty of drill. In addition to exercises worked on paper or blackboard, part of the daily lesson should be some mental algebra. Such easy questions as the following are most fruitful of good results:

1. What number must be added to x to make y?
2. By what number must 3 be multiplied to make a?
3. If a is one factor of b, what is the other?
4. What is the price in cents of 100 oranges, when x oranges cost 6 cents?

Etc., etc.

Such questions soon convince the average high school pupil that he does not know how to think in general terms, and by frequent practice such questions will gradually develop this necessary power. Miss McKelden further emphasized the importance of type forms in factoring; the review of arithmetic fractions when the algebraic fraction is introduced; the postponement of zero, fractional and negative exponents, the factor theorem, and cube root until the second or third year of the high school course.

The paper was followed by a general discussion, which was characterized by earnest and thoughtful opinion. Several suggestions were made as to changes that would improve the course in the first steps in algebra in the seventh and eighth grades of the Philadelphia schools. Many members believed that a syllabus might be compiled which would serve to unify and improve the teaching of algebra. A committee was appointed to enter upon this work and to make a preliminary report to the association: Gustave Legras, Chairman; E. C. Lavers, Miss Lao G. Simons, W. E. Barrett, George Alvin Snook.

The meeting concluded with a paper by Dr. Frederick H. Safford on "Inversion." Dr. Safford showed how easily a large number of elementary propositions could be established from this standpoint. Although pedagogical rather than theoretical papers are preferred by the association as a general rule, Dr. Safford's treatment of "Inversion" was so clear, elegant, and suggestive that he was followed most intently and given a unanimous vote of thanks.

The Middle States Association closes this year in a most prosperous condition. From the report of the secretary-treasurer, the association was shown to be free from debt. The receipts of the past year have been slightly in excess of the running expenses. Both the New York and Philadelphia Sections were reported to be actively at work. Communications reported that several local organizations of teachers of mathematics existed within the territory of the Middle States Association; that in the case of at least two of these, there had developed a strong interest in this association and a desire to become affiliated with it. A committee was appointed to consider this question and to report a plan whereby groups of teachers of mathematics already organized within the territory of the association might become sections of the association. Committee: T. S. Fiske, Chairman; Harry English, D. E. Smith, W. H. Metzler and President Crawley.

In response to a general communication from C. R. Mann, University of Chicago, and others, asking that delegates be appointed to a meeting to be held at Columbia University, New York City, December 27, at 2 P. M., to consider the formation of a Federation of Associations of Teachers of Mathematics and Science, and inasmuch as this association has already recorded itself as favoring a Federation of Associations of Teachers of Mathematics, the Committee on New Sections as given above was constituted a delegation from this association to the convention. All members of the association, who may find it convenient, were requested to attend this meeting.

The next meeting of the Middle States Association will be held at Teacher's College, New York City, Saturday, April 6, 1907. The following were elected officers for the ensuing year: President, Edwin S. Crawley, University of Pennsylvania, Philadelphia; Vice-president, John S. French, Jacob Tome Institute, Port Deposit, Md.; Secretary-Treasurer, J. T. Rorer, Central High School, Philadelphia. Council: Miss Jennie Van Vleck, Wm. H. Maltbie, Wm. H. Metzler, Miss Lao G. Simons, Gustave Legras, and Fletcher Durell.

Thirty-six new members were added to the roll of the association.

J .T. RORER, Secretary.

BIOLOGY SECTION OF THE CENTRAL ASSOCIATION OF SCIENCE AND MATHEMATICS TEACHERS.

The sixth annual meeting of the Section was held November 30 and December 1 at the University of Chicago. The meeting was called to order by the chairman, Mr. W. W. Whitney of South Chicago High School. The secretary's report was presented and was accepted.

The first paper, "Applied Bacteriology,"* was then presented by Miss Minna C. Denton of Lewis Institute. The discussion was opened by Mr. Hotzman of Robert Waller High School, Chicago. He told of a high school class of some forty-five members, a large per cent of which agreed that the most valuable work of their year's course in botany had been the work in bacteriology. He suggested the use of cultures with boiled potato as the medium before using agar or gelatine cultures. He also mentioned as an especially effective piece of work the comparison of death rates from diphtheria before and after the use of anti-toxin. An interesting and simple mathematical problem to be solved is, how many lives have been saved by anti-toxin. The subject introduces an opportunity for some missionary work in favor of vaccination.

Mr. Whitney then suggested the possibility of making similar use of the under-five death rate to show the value to the community of milk inspection.

Mr. Earl E. Ramsey of the High and Normal Training School of Fort Wayne, Ind., then read a paper entitled, "Inter-relations of Zoology and Physiology." Mr. Ramsey took the position that physiology is a necessary part of the study of zoology, forming a logical introduction to morphological studies. Taking a more literal interpretation of the subject, he devoted most of the time to a discussion of some depressing instances of a lamentable ignorance of morphological zoology on the part of some would-be teachers of physiology.

Mr. Conrad of the Richard T. Crane Manual Training High School asserted his belief that morphology should precede physiology, but that the study of it should be curtailed in order that it may be explained by physiology. He maintained that high school teachers are

*The paper will be published in full in this Journal.

prone to attempt too much. That the high school is but a sort of waiting room where pupils stay while growing up. That they may be benefited while in it, but that they are not made into students while there, that the student is merely begun.

The next paper on the program, "The Use and Value of Models in Teaching Zoology,"* was presented by Mr. Frederic Colby Lucas of Englewood High School, Chicago. Miss Smallwood testified as to the value of the models, quoting the statements of boys who had been in another teacher's class where the models had been used. Mr. Charles suggested the possibility of the models being more valuable to the pupils if fewer directions were furnished with them, and inquired whether remembering subjects by diagrams was not about on a par with remembering subject matter by the side of the page it was printed on. Mr. Mitchell of Hyde Park High School, Chicago, said that a laboratory was a place in which pupils were to express themselves, and that while some teachers chose one means to this end, another teacher might legitimately choose another.

Dr. John M. Coulter of the University of Chicago gave a brief but most interesting resumé of the recent discoveries concerning a group of plants, the Pteridosperms, which exactly fills in the gap between the ferns and the cycads. The investigations of the last few years have proved the "fossil ferns" of the coal measures to be not ferns at all, but a group of seed-bearing plants whose stamens differ scarcely at all from the sori of the fern, and whose seeds, which are of a very primitive sort, fit certain hypothetical, logical requirements of the theory of evolution of seed plants.

Dr. Chas. R. Barnes of the University of Chicago discussed the subject of respiration, and stated the present attitude of the physiologist with regard to the process. Respiration is no longer regarded as the oxidation of any certain substance by oxygen brought there for that purpose. It is believed that the last of assimilation results in dissimilation. Oxygen acts in a way as a depolarizer, assisting in the removal of some of the products of dissimilation.

Professor Otis W. Caldwell of the State Normal School at Charleston, Ill., gave a talk illustrated by the stereopticon on "High School Gardens in Relation to Teaching of Biology." Scenes from certain of the finest gardens of Germany and some from the Normal School grounds at Charleston were thrown on the scene. The possibilities of the school garden as a means for educating the public as well as for furnishing high school classes with materials and opportunities for observational work were well shown.

"How do You Teach Your Pupils to Know the Animals and Plants of Your Locality?" formed the topic of a discussion opened by Mr. Willard N. Clute of the Joliet High School. Mr. Clute regards the course in botany as generally planned in the Middle West as too full to admit of any work on teaching plant names. He would suggest that in the second semester of botany two courses be offered, one a

*The paper will be published in full ih this Journal.

course in classification, the other the present course in cryptogamic botany, and that the pupils be allowed to elect between them. If the study of classification must accompany the other work in the ordinary year's course, he would suggest beginning with trees or ferns in fall, studying algae in winter, and flowering plants in spring. Gray's Manual is, in his opinion, the only possible book for the work. In zoology he would give as much work of the sort as is possible with birds in spring and insects in fall. He advises making a key for the locality in which the class studies.

Because of illness, Mr. Herman S. Pepoon of Lake View High School was unable to open the discussion of "How May the Courses in Zoology and Botany be Made More Attractive to the Pupils?" By request Mr Hand of Wendell Phillips High School, Chicago, began the discussion. He named three factors in the solution of the problem—the personality of the teacher, the material, the equipment. On the first point his advice was, "Don't be icy." As to the second point he advised having live animals in the room. As to the third, he held that any teacher who knows what equipment he wants, and what use he can make of it, can persuade the school board of his needs, and can therefore be supplied with such equipment as will make interesting work possible.

The meeting was then adjourned until morning. At the opening of the morning session the election of officers for the ensuing year took place. The following were elected: Chairman, Thos. L. Hankinson, State Normal School, Charleston, Ill.; Vice-chairman, Thos. Large, Oak Park, Ill.; Secretary, W. L. Eckenburg, St. Louis, Mo.

Mr. John E. Cameron of Central High School, Kansas City, Mo., gave a lecture illustrated by many fine stereopticon views on "Bird Photography in the High School." He opened his lecture with a few remarks on methods. One important suggestion was to place twigs or leaves, of the sort that form the natural surroundings of the nest, in such a position that they will be in focus when the nest is photographed. Another was to have an attachment by which the camera could be so fastened to the tripod as to be moved by a ball and socket joint, so that the camera can be properly adjusted for photographing nests of water birds. The lecture with its many illustrations showed conclusively how valuable bird photography could be made in a high school course, and Mr. Cameron's fine spirit of enthusiasm made it seem very possible that such work should be done in many schools.

The lecture was followed by a paper by Professor Frank Smith of the University of Illinois on "Bird Migration Records and Their Value to the High School Pupil."* In the discussion which followed several people expressed a desire to possess duplicates of Mr. Cameron's slides. He promised to do what he conveniently could towards supplying such a demand. There was a very lively discussion of the value and methods of studying birds, bird nests, and bird migrations.

*The paper will be published in full in this Journal.

Professor Mitchell of Milwaukee reported great enthusiasm displayed by teachers and the public, when an opportunity for forming bird study clubs was afforded them. In response to remarks by Miss Smallwood and Miss Morey concerning the danger of pupils' migration records being inaccurate, Professor Mitchell said that he has learned to be very slow about expressing doubt as to the accuracy of a pupil's report. The mere fact that a given bird has not been formerly reported as appearing in a given locality at a given time is no proof whatever that the bird reported was not actually seen. A humming bird, dead from exposure, brought to him in March, and a white-winged cross-bill found in November were two out of several experiences which had led him to realize that official reports of migrations do not contain all the facts concerning all the birds.

Professor Smith suggested furnishing the pupils with printed slips bearing the names of birds likely to be seen at a given portion of the season, with places for records of appropriate data, such as meteorological conditions, locality, etc. These may be carried in a board back, and make possible accurate records without much trouble. For permanent records such a sheet as that in Walter's "Wild Birds in City Parks" is good. Professor Smith showed how interesting and valuable comparison of records made in various localities, or in the same locality at various times, may be.

Professor Mitchell announced that any who desired the Milwaukee migration bulletins could obtain them from him.

Professor Charles of DeKalb suggested that for classes who could not make accurate daily records, accurate week records were a possibility. He mentioned also a reflex camera by means of which snapshots of birds may be obtained.

Miss Morey suggested the desirability of preserving all the dead birds that are brought into the laboratory, and described the formalin method, which consists of injecting formalin into the body of the bird till it begins to escape from the mouth, hanging the bird up by its feet till the formalin no longer escapes, and then shutting it up in a tightly closed glass cylinder, or in a large test tube.

Making skins was suggested by Mr. Charles as a good substitute for mounting birds.

The meeting adjourned for another year.

ARTICLES IN SOME CURRENT MAGAZINES.

Scientific American Supplement, December 15, 1906: "How Seeds are Carried, IV," "Yellow Fever and Sanitation." December 22: "The Weed Fields," "The Measurement of Resemblance," "Are Crystals Alive?" "Geometry of the Hindus." December 29: "Light and the Visual Sense." January 5: "Regeneration and Transplantaion in Animals," "Electricity in the Treatment of Disease," "An Easily Made High-frequency Apparatus."

Science, November 30: "The Promotion of Agriculturl Science."

Photo-Era, November: "Improvements in the Diffraction Process

of Color Photography." December: "The Present Status of Color Photography."

Farming for October: "The Menace of Consumption in our Cattle and Hogs," "The First Principles of Woodlot Management." December: "Alabama's Great Farming Opportunities."

The School World, December, 1906: "The Arrangement and Equipment of a Geographical Laboratory," "Is an Accurate Figure Essential to the Proof of a Geometrical Theorem?"

Monthly Weather Review, August, 1906: "The Meteorological Opaics of Prof. J. M. Peinter," "Studies on the Thermo-dynamics of the Atmosphere," by Frank H. Bigelow; "Variation in Temperature over a Limited Area."

Scientific American, December 15: "The Poulsen Selective System of Wireless Telegraphy," "A Disease which Threatens the American Chestnut Tree." December 22: "Controlling the Colorado River and Salton Sea."

Physical Review for January: "A New Type of Alternating Current Galvanometer of High Sensibility," "Three-color Interference Pictures."

Open Court for January: "Alice in the Wonderland of Mathematics," "Conquest of River and Sea."

THE MINERAL PRODUCTION OF THE UNITED STATES IN 1905.

A most interesting chapter in the volume entitled "Mineral Resources of the United States, 1905," published by the United States Geological Survey, is that which contains a summary of the mineral production of the United States during that year.

In 1905, for the seventh time, the total value of our mineral production exceeded the enormous sum of $1,000,000,000. The exact figures for 1905 are $1,623,877,127, as compared with $1,360,883,554 in 1904.

As heretofore, iron and coal are the most important of our mineral products. The value of the iron in 1905 was $382,450,000; the value of the coal, $476,756,963. The fuels increased from $584,043,236 in 1904 to $602,477,217 in 1905, a gain of $18,433,981, or 3.16 per cent. Anthracite coal showed an increase in value of $2,904,980 from $138,974,020 in 1904 to $141,879,000 in 1905. The increase in value of the bituminous coal output over 1904 was $29,480,962, a combined increase in value of coal of $32,385,942 in 1905, or 7.3 per cent.

The gain of $262,993,573 in the total value of our mineral production is due to gains in both metallic and non-metallic products, the metallic products showing an increase from $501,099,950 in 1904 to $702,453,108 in 1905, a gain of $201,353,158, and the non-metallic products showing an increase from $859,383,604 in 1904 to $921,024,019 in 1905, a gain of $61,640,415. To these products should be added estimated unspecified products, including molybdenum, bismuth, tungsten, and other mineral products, valued at $400,000, making the total mineral production for 1905 of $1,623,877,127.

Besides the usual table and summary of quantities and values of the country's mineral output by products, the volume contains this year, for the first time, a summary, in tabulated form, of the value of the mineral products by states. These tables were compiled by Mr. Wm. Taylor Thom.—*U. S. Geological Survey Bulletin 260.*

BOOK REVIEWS.

Entomology with Special Reference to its Biological and Economical Aspects. By Justus Watson Folsom, Sc.D. 8vo; 485 pages; 300 figures; $3.00 net. P. Blakiston's Son & Co.

This highly useful book was reviewed in the December issue, but through an oversight the name of the publisher was omitted.

Nervous System of Vertebrates. By J. B. Johnston, Ph.D. 8vo.; xx + 370 pages; 180 figures; $3.00 net. P. Blakiston's Son & Co.

This is primarily a text-book on the morphology of the nervous system of vertebrates, but the author has treated the subject from the functional point of view and attempted to show the factors which have determined the course of its evolution. Although beyond the capacity of the high school pupil, this book should be intelligible and helpful to the teacher in getting a clearer notion of the mechanism which is the anatomical basis for animal behavior. The style is clear, the illustrations are numerous and effective. The author is one of the leading investigators in the country in this particular field of research. In this book decided advance has been made in the method of presentation of an important but rather difficult subject.
an important but rather difficult subject. FRANK SMITH.

Behavior of the Lower Organisms. H. S. Jennings, Ph.D. 8vo.; xiv + 366 pages; 144 figures; $3.00 net. The Macmillan Co. (Columbia University Biological Series, Vol. X.)

The teacher who is interested in animal behavior as illustrated by Protozoa, Cœlentera, Echinoderma, worms and Crustacea will find in this book a very full treatment of the observed facts of the reactions to various sorts of stimuli as manifested by animals of the first two groups and a less extended account of the behavior of animals of the other groups named. The last hundred pages is given to an analysis of the behavior of such organisms and to a discussion of the theories involved. A clearly written, able treatment of the subject by a leading investigator. FRANK SMITH.

Exercises in Zoology. W. Whitney and F. C. Lucas. With a special series of *Projection Exercises* by *J. H. Holmes.* 21 × 24 cm. 168 pages, 30 blanks for tables and diagrams. $1.00. Neeves Stationery Co., Chicago.

Two of the authors of "Studies in Animal Life," which has been in use in the zoology classes of the Chicago high schools for several years, have collaborated with Mr. Tracy H. Holmes in the preparation of a set of directions for laboratory and projection exercises for pupils of secondary schools. Each of the authors has had several years of successful experience in biology work in leading Chicago high schools, and they have profited by the experience of their associates in the same kind of work.

The guide has several special features which differentiate it from previous books of the kind and increase its usefulness. The loose-leaf plan has been adopted. Each exercise is planned to require a single

or double fifty-minute period and has a heading in the form of a question which suggests a problem to be worked out during the period. The sheet containing directions for an exercise is to be detached and included with the student's notes on that topic. The exercises for each large group of animals are devoted to a fairly careful study of a representative form and to comparative studies of a few related forms and under the heading, "Further Studies and Review," are given a large number of topics from which selections may be made requiring supplementary reading and study. A dozen or more exercises in formal physiology are introduced and more than forty exercises involving a projection outfit have been contributed by Mr. Holmes. More work than can ordinarily be accomplished in a year has intentionally been provided and thus abundant material furnished from which selection may be made in accordance with the equipment and environment of the school and the preferences and ideals of the teacher. The loose-leaf plan and separate exercise arrangement adapt the guide for use in short courses and to any order of treatment of animal groups that may be preferred.

Throughout the guide, the directions are in the form of questions when practicable and directions of the identification type are used only when obviously preferable. The anatomical studies have been consistently subordinated to the study of function and of the activities of the living animal; and numerous practicable exercises for field and home study are presented. Numerous tables for various comparative and review exercises are provided for the student to fill out as an aid in the organization of the knowledge which he has acquired. This guide seems especially commendable in its general plan and in the character of its content. It should be highly useful in secondary schools, large or small.

FRANK SMITH.

Physics Theoretical and Descriptive, by Henry C. Cheston, J. S. Gibson and Charles E. Timmerman, Instructors in Physics in New York City High Schools. Pp. xvi + 373. 252 figures and illustrations. 13.75 × 18.75 cm. D. C. Heath & Co., Boston.

I take it for granted, without discussion, that in teaching physics the teacher will depend (1) upon the pupil's individual laboratory work, (2) upon lectures, (3) upon problem work, and (4) upon some good text.

Most teachers of physics use these four methods in presenting different phases of the subject.

Whether the approach to a new subject should be through the pupil's individual laboratory work or by way of the lecture, accompanied by qualitative experiments, is a matter about which there is probably a difference of opinion. The authors of this book say that "it is recognized by all as a sound pedagogical principle that laboratory work performed by the pupil should constitute his introduction to each new subject or principle." This is a very sweeping statement. I wonder if their pedagogical principles would prevent one from introducing a new subject or principle to the pupil in the lecture room.

The lecture provides a means of looking at the subject in a large

way. The laboratory experiment presents a small portion of a subject for minute examination. However one may feel about the comparative value of the lecture or the laboratory, as a means of presenting a new subject, most teachers would agree with the next statement: "It is also generally conceded that the experiments and all that pertains to the individual laboratory work which the pupil is expected to do, should be eliminated from the text-book, and placed in a laboratory manual."

What, then, is left for the text-book? It is not to be a laboratory manual. It is not to take the place of the live, personal teaching of the lecture room. In my use of a text-book I want the book (1) to contain a clear, concise statement of the principles which are to be studied, presented in language which the pupil can comprehend, (2) illustrated by cuts and diagrams, and (3) well supplied with practical applications of the principles which are studied, with (4) some treatment of the subject from a historical point of view.

How does the book under discussion meet the conditions just specified?

As regards clear and concise statements of principles.

The selection of material in the book and order of presentation is good, but may be varied to suit the teacher's needs. I like to place as much as possible of the work in mechanics late in the school year—especially kinematics and kinetics, because of their difficulty. I like to take up magnetism and electricity about the middle of the year, and leave light till June.

In the main I find the statements clear and concise. Velocity is not defined correctly. Speed is defined, and called velocity. Velocity a vector quantity compounding velocity. The Kinetic Theory of the Constitution of Matter is well put. The statements of fact and the mathematical demonstrations are correct, and, in many cases, exceptionally well expressed.

The discussion of light is good, and the geometrical demonstrations are in an appendix where they belong. In particular I would call attention to the discussion of images as being well expressed and accompanied by excellent diagrams. In the subject of sound, the authors plunge at once into a technical discussion of the topic, without consulting the pupil's previous experience.

In Heat, one reads that "Temperature is determined by the mean square of the velocity of the molecules." This may be true, but it is hard for pupils to appreciate, and is cited only as an example of putting the final accurate knowledge expressed scientifically before the pupil, without leading up to it by easy steps.

This tendency of the authors not to lead up to new ideas by easy steps, thus connecting the pupil's experience with the new idea, is an unfortunate mistake.

Cuts and diagrams are good. I note particularly a cut representing a sound wave, cuts showing action of steam engine and gas engine, and diagrams in the subject of Light. Graphical representations of dependent variables are well executed.

As is usually the case with a new book, some errors creep in, and some of the cuts in this book are not absolutely accurate, e. g., in one case the same beam of light is labeled green at one end and violet at the other (p. 237).

Practical applications of the principles studied are few, in fact there is a very great lack of illustration of the principles involved, taken from daily life, and (excepting, possibly, the chapters on electricity) very little to connect the treatment of the topics with the pupil's previous experience.

This, from my point of view, is a serious mistake, but no doubt the authors justify the omission from a different point of view.

There is little reference to men of science, who have labored to give the world the knowledge so accurately set forth, and almost nothing concerning the historical development of the subject.

It seems to me that the authors of the book have not sufficiently taken into consideration the pupil's point of view, and in this respect are pedagogically wrong. Its successful use would depend entirely upon the ability of the teacher to supply the vital elements that are lacking, thus making the subject interesing and throbbing with life. The view-point appears to be that of men well grounded in their subject, expressing themselves in too technical a manner for beginners, and not as teachers of boys and girls. I can conceive of teachers who, by the lecture, and from their own fund of experience, are able to supply these vital elements, and it may be that it is for this teacher's use that the book is written. If so, it is well written.

Personally, I like the book so far as it goes, and should like to have it on my desk, but should depend very little upon it in the pupil's hands, as a means of developing the pupil's interest or power in the subject. All that the teacher would have to do.

If these vital elements were introduced and parts of the text simplified, it would be a strong book. As it stands, it is simply another text-book of physics, considerably better than the average.

A. B. KIMBALL.

ERRATUM.

The article on page 53 of the January issue should have been credited to Mr. J. F. Thompson of the Richmond High School instead of Mr. Ellabarger.